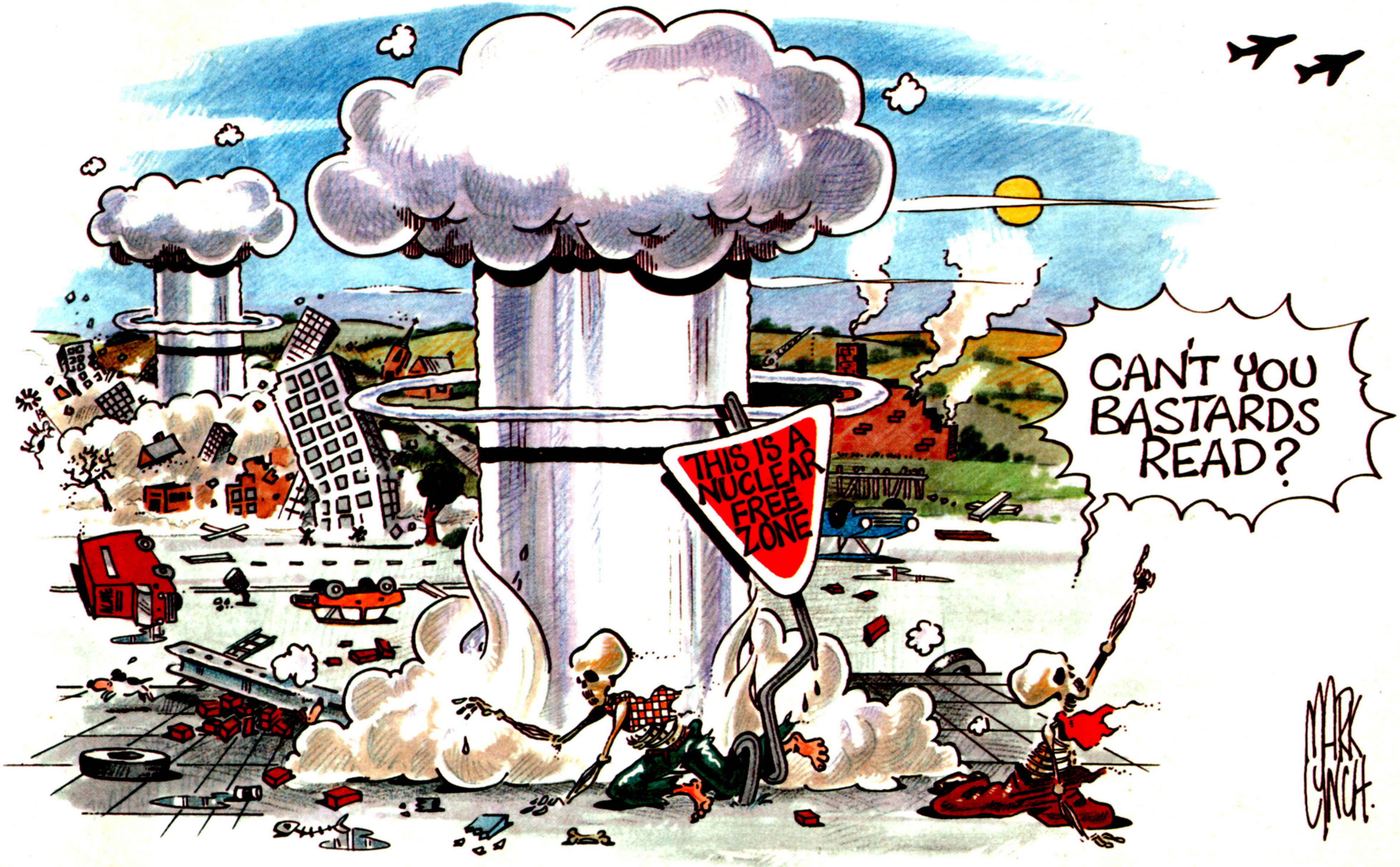
MARK LYNCH

CAN'T YOU BASTARDS READ?



(cover of Mark Lynch's 1988 book, Grafton Books)

A PENGUIN SPECIAL

C. E. M. JOAD

Why War?

"My case is that war is not something that is inevitable, but is the result of certain man-made circumstances; that man can abolish them, as he abolished the circumstances in which the plague flourished."

NEW REVISED EDITION

C. E. M. Joad

C. E. M. Joad, M.A., D.Lit., was born in 1891, educated at Blundell's School, Tiverton, and Balliol College, Oxford, and entered the Civil Service in August 1914. He was in the Ministry of Labour from 1914 to 1930. He then resigned and became Head of the Department of Philosophy and Psychology at Birkbeck College, University of London. He is the author of numerous original books of philosophy, having chiefly established his reputation as an interpreter of philosophy for the general public. His *Guide to Philosophy*, published in 1936, has been reprinted nine times. Is also the author of two unusual autobiographical books, the *Book of Joad* and the *Testament of Joad*. Finally, he is well known as a pacifist.

He is a keen rider, a great walker, plays hockey and tennis.

WHY WAR?

by

C. E. M. JOAD

AUTHOR OF

Guide to Philosophy
Guide to the Philosophy of Morals and Politics
The Book of Joad
Guide to Modern Thought, etc.

(NOTE THAT CYRIL JOAD LED THE 9 February 1933 OXFORD UNION "KING AND COUNTRY" PACIFISM.)

First published 1939
Reprinted September 1939

PUBLISHED AS A 'PENGUIN SPECIAL' BY
PENGUIN BOOKS LIMITED
HARMONDSWORTH MIDDLESEX ENGLAND

Mr. Churchill and Sir Norman Angell.

The process, it is obvious, is not one that makes for security. One does not, if one is wise, insure oneself against fire by devoting all one's savings to the storing up of explosives. Apart from the vested interest in war of the armament makers, the professional interest in war of young men trained in the use of modern weapons and anxious to exhibit their technical skill, is it not obvious that those nations which possess great armaments will, sooner or later, use them as surely as children will use elaborate and exciting toys? The most convincing comment that I have heard on the whole lunatic business was made at a meeting which I attended as an undergraduate at Oxford in the year before the war. The meeting was addressed by a Cabinet Minister. "There is," he said, "just one way in which you can make your country secure and have peace, and that is to be so much stronger than any prospective enemy that he dare not attack you, and this is, I submit to you, gentlemen, a self-evident proposition." A small man got up at the back of the hall and asked him whether the advice he had just given was the advice he would give to Germany. A faint titter ran through the meeting—the audience was, I suppose, above the average in political intelligence—but there was no applause. Presently, the time came for speeches by the audience. In a speech equally devastating to the Cabinet Minister, and convincing to me, the questioner proceeded to drive home the moral which his question had implied. "Here," he pointed out, "are two nations or groups of nations likely to quarrel. How shall each be secure and keep

the peace? Our Cabinet Minister tells us in the profundity of his wisdom, that both will be secure, both will keep the peace when each is stronger than the other. And this, he thinks, is a self-evident proposition." This time there was loud applause. It remains to add that the Cabinet Minister was Winston Churchill, his questioner Sir Norman Angell.

(IMPLICITLY ASSUMES BOTH SIDES TO BE EQUIVALENT MORALLY AND IN ECONOMIC VIABILITY. ACTUALLY, DICTATORSHIPS ARE NOT AS VIABLE IN AN ARMS RACE, BECAUSE OF CENTRALIZED, MONOLITHIC CONTROL WHICH IS SHORT-SIGHTED AND FAILS TO INSPIRE AND MOTIVATE PEOPLE IN THE LONG TERM LIKE CAPITALISM)

(NOTE ALSO THAT SIR NORMAN ANGELL AUTHORED THE 1909 PACIFIST BOOK "THE GREAT ILLUSION", CLAIMING THAT SINCE WARS ARE EXPENSIVE THEY ARE A FINANCIAL ILLUSION.)

(GERMANY TOOK NO NOTICE OF ANGELL IN 1914/1939, BUT APPEASERS DID!)

at some future date. "Standing up" to Hitler means being prepared to fight a war whose object would, presumably, be to preserve liberty and democracy, to overthrow Fascism and—we must, I suppose, add—to lay the foundations of a lasting peace. History, as I have tried to show, affords no warrant for supposing that the war would have any such results. But while it is impossible to predict the *ultimate* results of a modern war, those which seem reasonably probable include the destruction of most of what goes by the name of civilization in the contemporary world. **VAGUE!**

EXAGGERATIONS OF BOMBING EFFECTS:

The Character of the Next War.

The horrors with which the invention of the bombing aeroplane has invested war are by now familiar, but few of us, in spite of the crisis through which we lived in September, 1938, have any conception of the nature and effects of the large-scale bombing of London. It is not merely that gas and explosive bombs will kill civilians and destroy houses; it is not merely the horror of the direct hit upon the hospital full of wounded, or of the thermite bomb that sets fire to the asylum. Scarcely less harrowing, though I think, less generally regarded, is the prospect of the destruction of the lighting and heating systems of London with the resultant dark streets and unwarmed houses, of the ventilating apparatus that operates in the tubes by the bombing of the power stations with the resultant suffocation of those who have taken refuge in the tunnels, of the smashing of the drains to let loose into the streets their burden of sewage laden with the germs of disease to complete the destruction wrought by men, of the jamming of the roads leading from London to the country by hordes of panic-stricken fugitives, fleeing from the terror in the air, without petrol for their cars, without food, without shelter, of the crowds of starving men

who, presently, will spread over the countryside, looting and plundering. . . . I have read a number of books on this subject and the weight of opinion seems to be decisively in favour of the view that whatever protection we may devise for civilians, we cannot preserve the fabric of the civilization in which we live. Water, gas and light mains, sewers, roads, transport offices, factories, homes, railway stations, telephone exchanges, standing crops, cattle—all are vulnerable.

We must, then, it is clear, face the possibility of the breakdown of the social services, the cutting of the nerves which keep our social system alive, and the relapse of society into a chaos of panic-stricken individuals fighting each for his own hand, save on one condition, the establishment of a military dictatorship which imposes upon the country an iron discipline, suppresses the right of criticism, stifles grievances and shoots grumblers and dissidents at sight. Such is the most probable result of a war fought under modern conditions for idealistic ends. In a word, all the liberties that we now cherish and would be fighting to preserve would disappear. Through sheer pressure of circumstances, the war to save democracy would kill democracy within twenty-four hours of its declaration.

Gangsters and Troglodytes.

There is one further possibility. If, as may well be the case, the next war, or the next war but one, brings about the destruction of our civilization, it will be succeeded by a series of governments of the gangster type envisaged in Mr. Wells's *Shape of Things to Come*. In a half-starved world gangs will fight for food and plunder, and the most successful will become the government. What sort of end is this to a war for liberty, for democracy, and for civilization? And what sort of life will our descendants be living after a series of such wars?

Issued for the Ministry of Home Security
by the Ministry of Information

FRONT LINE

1940-41

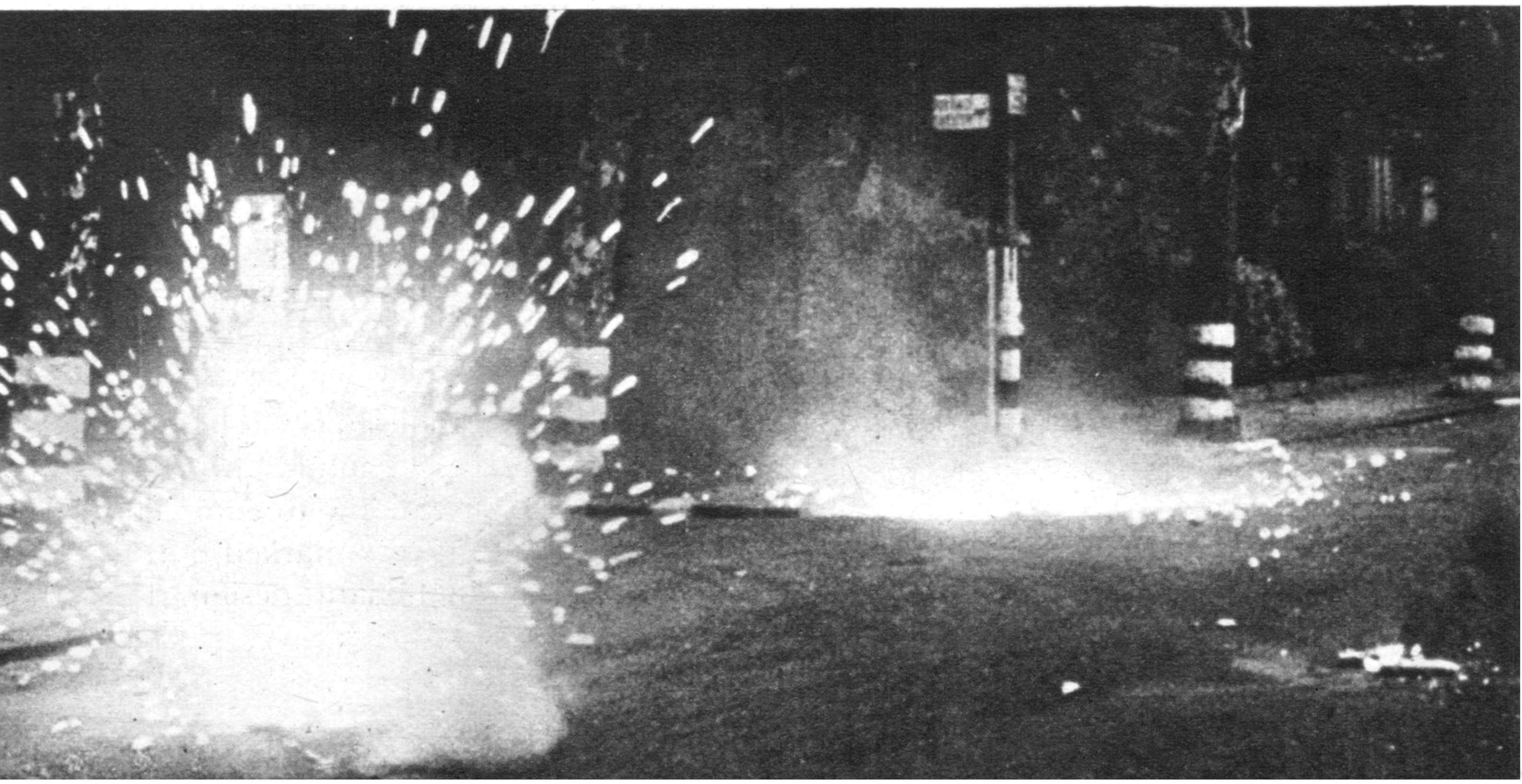
The Official Story of the
CIVIL DEFENCE
of Britain

1942
London: His Majesty's Stationery Office

4.56 P.M., 7th SEPTEMBER, 1940 ; the sirens announced the attack on London.

FIRE-BOMBS rained on London

They did not all fall on roads



THE LUFTWAFFE SOUGHT A KNOCK-OUT BLOW. The first impact of the attack fell on the docks. The great day raid of 7th September, 1940, which was continued throughout the night and renewed on many nights after, left miles of fires blazing along either bank of the Thames. This is St. Katherine's Dock on the night of 11th September.

THE SEARCH GOES ON. Throughout the night and all next day wardens, rescue men and ambulance men burrowed into the wreckage of this house, looking for its occupant. an old lady. She was under the stairs.

THE FIRST BOMB fell upon Hoy in the Orkneys on 17th October, 1939. The first civilian was killed at Bridge of Waith, Orkney, on 16th March, 1940, a half-year after the outbreak. The first bombs on the mainland of Britain for 22 years fell near Canterbury on the night of 9th May. On 24th May, the first industrial town was attacked—Middlesbrough. The first bombs on the London area hit plough-land at Addington in Surrey on 18th June.

This was on the night after the day of the French surrender, and the German Air Force gave quick token of its next intentions by sending night bombers over Britain in some numbers. Strategists call the movements and field preparations leading up to a battle the approach. The 18th June opened the Approach to the Battle of Britain. From that day until 8th August, the Luftwaffe reorganised after its continental exertions, prepared its newly won bases, and gave its heavy bomber squadrons practice in the neglected arts of night navigation.

"The attacks of our Luftwaffe are only a prelude. The decisive blow is about to fall."

The German News Bureau to Germany, 30th August, 1940.

LONDON KNEW what was in store. The Air Minister had given warning that the Battle of Britain had thus far left the enemy's heavy-bomber force mainly inactive, waiting on its cross-Channel aerodromes. Göring had said bluntly that the night raids of July and August were mere armed reconnaissances. For years Londoners had been instinctively aware of the shape of things to come. Now they understood that things were coming to them, and they were ready. Ready, that is to say, as far as any city could have been ready for a test that can never be understood until it is experienced; ready for sacrifice and mentally stripped for action against the unimaginable.

On 7th September Göring told the German people; "This is the historic hour when our air force for the first time delivered its stroke right into the enemy's heart."

And on 7th September it came. That gloriously fine Saturday afternoon a senior Fire Officer off duty was having a leisurely tea in the shade on a Dulwich lawn.

There were in all 375 bombers, and fighters, in waves. They dropped their bombs on Woolwich Arsenal, on the immense gas-works at Beckton—London's first civil target—on the docks at Millwall, on the docks at Limehouse, and at Rotherhithe, on the docks by Tower Bridge, on the Surrey Docks, on the West Ham Power Station; they went on across the City and Westminster and bombed a crescent in Kensington.

This was daylight bombing; the Germans could see, and while many of their bombs went wide among the little dockland houses and the tenements, many found more legitimate marks. It was London's only big day attack; and it taught her Civil Defenders, when later they looked back upon it, how much the Royal Air Force did for the capital when it forced the enemy into night-bombing. The docks blazed along all their miles, on both banks of the river, and the wondering watchers looking down-river from the central bridges saw the sun's own light grow pale beside the crimson glare that hung and flickered above the eastern boroughs.

By 6 o'clock the day raiders had gone. There was a two-hour break in the attack. At ten minutes past eight the night raiding force appeared, guided straight to its targets

by huge riverside fires which it set out to stoke with high explosive and incendiary bombs. Until 4.30 next morning the droning procession went on. Some 250 bombers were over the city. When the last departed, there were, as product of the day and night attack, nine conflagrations (huge spreading areas of flame), nineteen fires that would normally have called for thirty pumps or more, forty ten-pump fires, and nearly a thousand lesser blazes, of which no more can be said than that scores of them would have been front-page stories in peace time.

In the dockside boroughs thousands of houses were destroyed or damaged by bomb and fire, though many of them not irreparably. The factories that sprinkle London and the railway lines that run so plentifully near the river had their inevitable share of hits. Three of the main line terminal stations were out of action.

Four hundred and thirty men, women and children lost their lives and 1,600 were seriously wounded. Fire did little of this slaughter: it was wreaked by collapsing walls and ceilings, by the direct impact of bombs, by flying brick and stone, by swift javelins of splintered glass.

THOSE WHO WENT TO SHELTERS began a new kind of night-life. Some took over the Tubes, camping out in this fashion—Elephant and Castle Station, 11th November, 1940.

THE NEW LIFE BECOMES ORGANISED. Food, medical services, entertainments were provided—an all night canteen in a Tube tunnel, one of London's biggest shelters.

THE NIGHTLY MIRACLE. Another kind of shelter life was led in something like a million back-garden Andersons. Four people and a dog were trapped in this one when a bomb blew a crater alongside. All came out alive.

So far was all this from panic that it took three months for the population of the twenty-eight central boroughs to drop by about 25 per cent. from a little over 3,000,000 (the figure before heavy bombing began) to 2,280,000 at the end of November. In a group of the most heavily bombed eastern boroughs the pre-war population of 800,000 had fallen to 582,000 before the blitz began; for four months it had dropped steadily to 444,000; by 31st December a fall of 23 per cent. These figures do not spell panic, and a further substantial fall in 1941, after continuous heavy raiding had ceased, completes the evidence that those who went did so in cold blood, for practical reasons as valid for their hard-pressed city as for their private selves.

But what did all this mean to the average Londoner? In November, inner London (the county) contained some 3,200,000 people. Not more than 300,000 of these were in public shelter of any kind, half of that number at most in those larger shelters on which the limelight shone so exclusively. Nor is this all; in domestic shelter (Andersons, small brick shelters and private reinforced basements) there were no more than

1,150,000 people. Thus of every hundred Londoners living in the central urban areas, nine were in public shelter (of whom possibly four were in " big " shelters), 27 in private shelter, and 64 in their own beds—possibly moved to the ground floor—or else on duty. Particular big shelters, and for a few nights the tubes, were overcrowded, but there was public shelter for twice the number who made use of it. In outer London, with a population of some 4,600,000, there were in November 4 per cent. in public shelter, 26 per cent. in domestic shelter, and 70 per cent. at home or on duty.

In the last great war there had been outbursts of hate against the distant enemy, and shops with German names had been wrecked. This time the citizens did not stop for such things. After the first shock of realisation they found no more need for direct recrimination than does the soldier. Like him, they got on with the job and waited their chance. Neither in this nor in any other way was there a sign of instability ; no panic running for shelter, no white faces in the streets (though plenty of taut, grim ones), no nerve disease. In all London, the month of October saw but twenty-three neurotics admitted to hospital. The mind-doctors had rather fewer patients than usual.

Balham High Road, London, 15 October 1940

BLOCKED ROADS. The morning of 12th May: each raid sets the police still another traffic problem.

ENORMOUS CRATERS. At the Bank, where the road collapsed into the subway beneath. A temporary bridge was thrown right across it.


CITY OF COVENTRY
PREVENTION OF TYPHOID FEVER
In view of present damage to DRAINAGE communications in the City, special precautions against Typhoid Fever are advised:
BOIL ALL DRINKING WATER

LIVERPOOL : Lord Street ; South Castle Street ; Customs House in the background.

The outcome may be seen in the following table, which shows coastal bombing to November, 1941, in round figures.

Town.		*Number of Raids.*	*Civilians Killed.*	*Houses Damaged.*
Fraserburgh	...	18	40	700
Peterhead	...	16	36	700
Aberdeen	...	24	68	2,000
Scarborough	...	17	30	2,250
Bridlington	...	30	24	3,000
Grimsby ...	...	22	18	1,700
Gt. Yarmouth	...	72	110	11,500
Lowestoft	...	54	94	9,000
Clacton ...	...	31	10	4,400
Margate	...	47	19	8,000
Ramsgate	...	41	71	8,500
Deal ...	...	17	12	2,000
Dover ...	...	53 (and shelling)	92	9,000
Folkestone	...	42	52	7,000
Hastings ...	...	40	46	6,250
Bexhill ...	...	37	74	2,600
Eastbourne	...	49	36	3,700
Brighton / Hove ...	}	25	127	4,500
Worthing	...	29	20	3,000
Bournemouth	...	33	77	4,000
Weymouth	...	42	48	3,600
Falmouth	...	33	31	1,100

THE STORY OF HEAVY RAIDS, Chapter I, ended in May, 1941, though the story of civil defence did not. How far the Blitzkrieg itself may come to have a second chapter is a question to which the answer is hidden in the dark recesses of the minds of the German General Staff. When they calculate the chances, there may be many a new prospect or device that will tempt them not to regard too closely the lesson of their past experience. But if, and in so far as, they may think it salutary to look back, what will they see as their achievement?

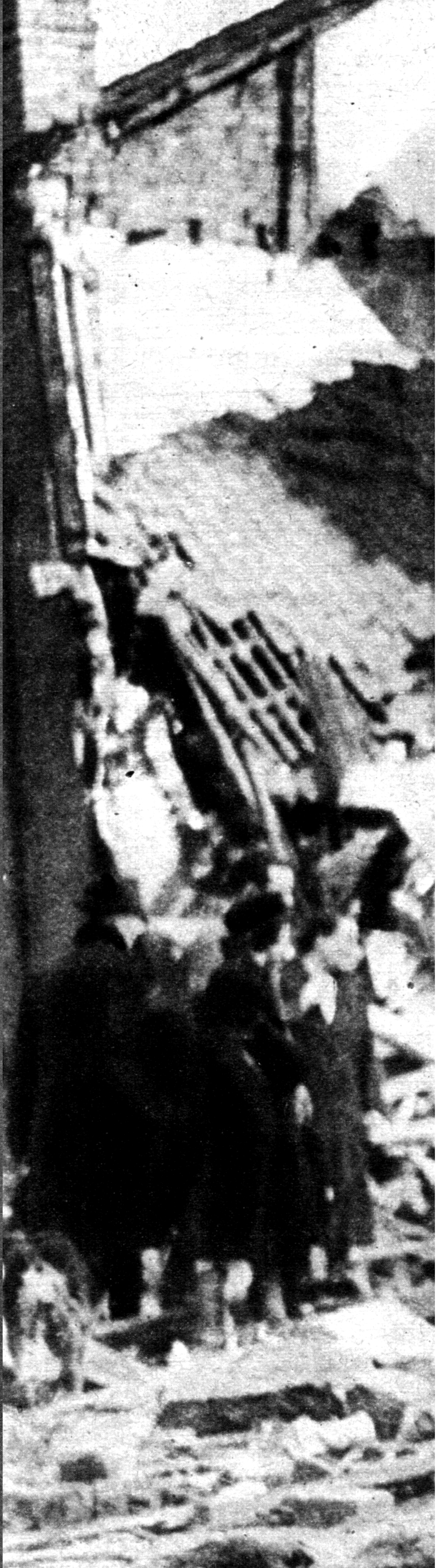
They will see that (as their propaganda showed) they misread their enemy's mind and miscalculated his attitude to the war. They will see that they were not bombing a deceived, disillusioned and dispirited people to whose other burdens air bombardment would be an intolerable addition. Such an enterprise, which they had undertaken with some success elsewhere (and which may yet be carried to a conclusion against them in their turn) was this time denied them. When they look back, they can see only failure.

NORTH-EAST HERO. In one of the countless tip-and-run raids with which the Luftwaffe harried Britain's coastline this 14-year-old schoolboy worked all through the night rescuing buried people.

"I see the damage done
by the enemy attacks;
but I also see,
side by side with
the devastation
and amid the ruins,
quiet, confident, bright
and smiling eyes,
beaming with a consciousness
of being associated
with a cause
far higher and wider
than any human
or personal issue.
I see the spirit
of an unconquerable people"

WINSTON CHURCHILL

April 12th, 1941



Aldwych, 30 June 1944, V1 attack

A PENGUIN SPECIAL

Edward Glover

THE PSYCHOLOGY OF FEAR AND COURAGE

A PENGUIN SPECIAL

THE PSYCHOLOGY OF FEAR AND COURAGE

BY

EDWARD GLOVER

(Published for Blitz air raids in 1940)

PENGUIN BOOKS

HARMONDSWORTH MIDDLESEX ENGLAND

41 EAST 28TH STREET NEW YORK U.S.A.

AUTHOR'S NOTE

NOTE.—Chapters I to IV were originally prepared for purposes of broadcasting. An abbreviated version of the section on " Rumour " was broadcast on July 16th, 1940, in the " Calling all Women " series. Portions of the other chapters were broadcast on July 25th, 1940, under the title " Talking it Over: the Handicap of Temperament." I am indebted to the B.B.C. for permission to include the material here.

E. G.

Real knowledge, for example, is one of the best antidotes to unreal fear. *Useful action* is also an excellent preventive, and *vigorous preparation to meet real danger* will enormously reduce unreal fear. The strength of a common purpose will do the rest. Knowledge, a common purpose, and preparedness for action. These are the remedies for faintness of heart in the face of danger.

22

Now as to preparation. You may recall that when Napoleon was asked how he was always able to give an instant decision in a crisis, he replied: "Because I constantly prepare every detail in advance." Here is a discipline you can readily cultivate. Always make a point of knowing beforehand *exactly* what you are going to do in an air raid; whether you find yourself in house, street, train, bus or shelter. Have it word perfect.

23

A stray crowd packed into a cinema is likely to panic at the cry of "Fire." There are no common bonds between the people concerned; and there are no leaders. Each one is for himself.

34

Already we have the advantage that we are fighting not only for our lives and homes but for the immemorial cause of human liberty. But that is not enough. Provided we are united with our leaders in a common effort, real danger will never sap our morale. The greatest danger to our morale is unreal fear.

36

However hackneyed the adage: "United we stand, divided we fall," it is still the most profound of psychological truths.

119

Take, for example, the ideas of communism and fascism, which obviously overstep the barriers of nationalism. A moment's reflection will show that these ideas do not unite nations. On the contrary, unless the peoples concerned are deprived of freedom of speech, thought and political power, they cause acute dissension rather than unity. They disintegrate.

121

one of the greatest flaws of the Nazi political philosophy is its stupendous over-estimation of the significance of the State. Compared with the organisation of an individual, the State is an almost amorphous mass.

122

For if you want children's minds to develop, you must not poison them with important illusions. You must let their minds be free to observe and judge.

126

Euripides:

"What then is Wisdom? What of man's endeavour?

. . . .

To stand from Fear set free, to breathe and wait,
To hold a hand uplifted over Hate.
And shall not Loveliness be loved for ever?"*

* *Bacchae*. (Gilbert Murray's translation.)

128

NUMBER AND CLASSIFICATION OF OFFICIAL EVACUEES IN GREAT BRITAIN IN 1939 AND 1940

900,000 of the 1.5 million returned to the target areas after four months of war.	September, 1939		January, 1940	
	Number	Percentage Distribution	Number	Per cent of Those in September, 1939
1. Unaccompanied school children	826,959	56.1	457,600	55
2. Mothers and accompanied children	523,670	35.5	64,900	12
3. Expectant mothers	12,705	0.9	1,140	9
4. Blind persons, cripples, and other special classes	7,057	0.5	2,440	35
5. Teachers and helpers	103,000	7.0	46,500	45
Total	1,473,391	100.0	572,580	39

Source: R. M. Titmuss, *Problems of Social Policy* (London: H.M. Stationery Office, 1950), pp. 103 and 172.

HOME OFFICE

CIVIL DEFENCE

Manual of Basic Training

VOLUME II

BASIC METHODS OF PROTECTION AGAINST HIGH EXPLOSIVE MISSILES

PAMPHLET No 5

LONDON: HIS MAJESTY'S STATIONERY OFFICE
1949

SIXPENCE NET

Domestic Shelters (for household use)

(*a*) ANDERSON SHELTER. This shelter was designed for erection outside the house. It consisted of 14 gauge corrugated steel sheets, steel angles, ties and channel irons. It was normally sunk about 3 ft. into the ground and covered over with earth to a minimum depth of 15 in., which, with the 14 gauge corrugated sheet gives the equivalent of 18 in. of earth.

The standard shelter was 6 ft. 6 in. by 4 ft. 6 in. by 6 ft. high. It was designed to shelter six persons, but was capable of being lengthened to accommodate eight, ten or twelve persons; or of being shortened to accommodate four persons.

Unless the entrance was screened (within 15 ft.) by a building or existing wall, a screen wall had to be provided. Trouble was sometimes experienced due to flooding by subsoil water in which case the below ground portion was tanked by a lining of cement concrete.

The shelter was, on occasions, erected on the surface, which involved casing it in cement concrete. The result was efficient but expensive.

(*b*) MORRISON SHELTER. This shelter was designed for use in a house and its chief function was to protect the occupants from being crushed by the collapse of the building. Protection against blast and fragments was provided by the walls of the house, which were sometimes specially thickened for this purpose.

It consisted of a steel table measuring 6 ft. 4 in. long by 3 ft. 10¾ in. wide. It provided sleeping accommodation for two adults and a child, or a considerable number of small children in a sitting position, when used as a school classroom shelter.

(*c*) STRUTTED REFUGE ROOM—STRUTTED BASEMENT. The object of this form of shelter was the same as the Morrison shelter, i.e. to provide strutting to prevent the collapse of the room and to use the walls as protection against blast and fragments. Strutting was either steel or wood and the design and strength suited to the weight to be supported.

(*d*) SMALL TRENCH OR SMALL SURFACE SHELTER IN GARDEN. This type of shelter needs no special comment.

HOME OFFICE

AIR RAID PRECAUTIONS

DIRECTIONS
FOR THE ERECTION AND SINKING OF THE GALVANISED CORRUGATED STEEL SHELTER

(ANDERSON SHELTER)

February 1939

London family who survived in Anderson shelter during Blitz, when the shelter absorbed the blast (earth was blown off) in 1940

A.R.P. (O) 10

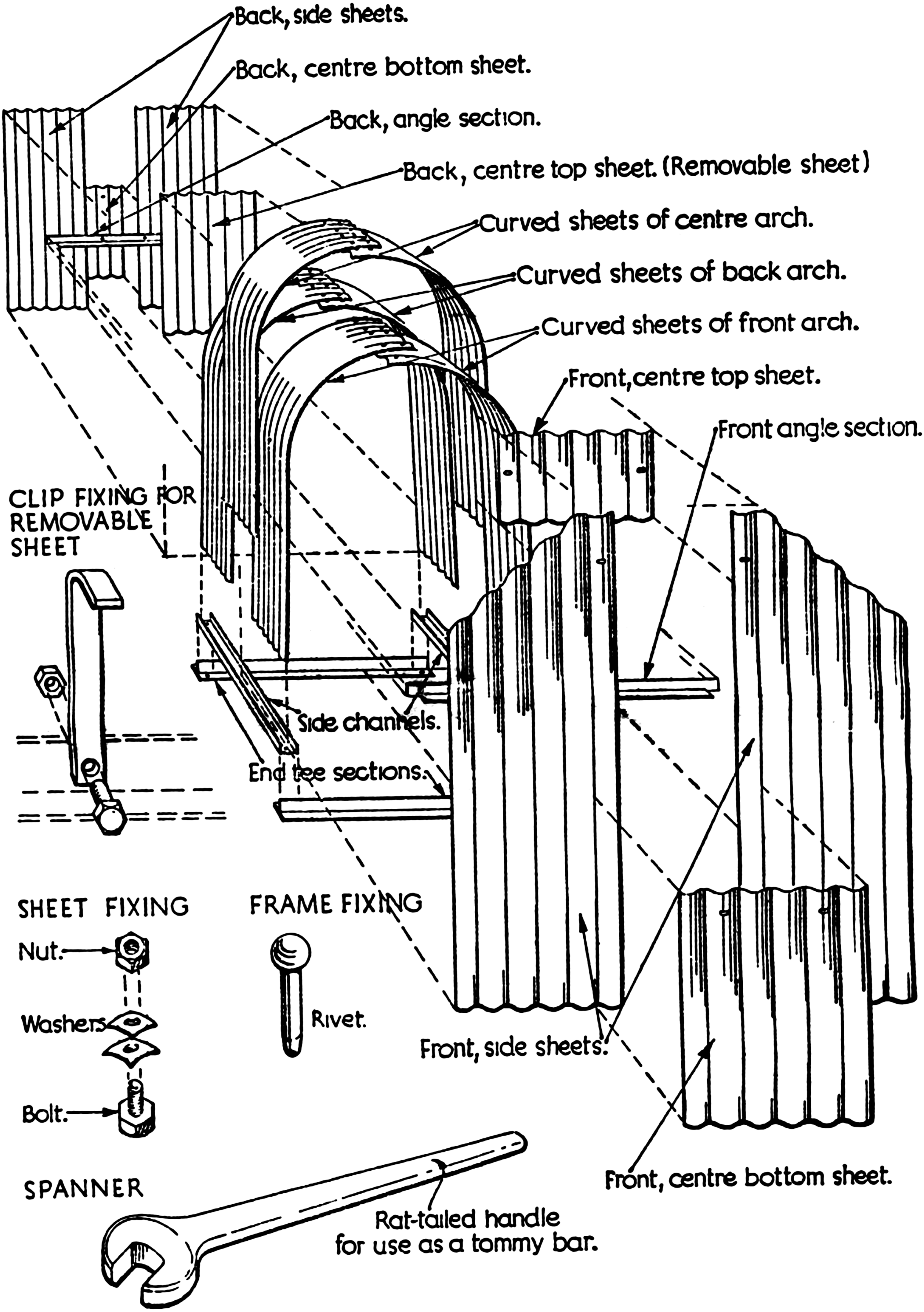
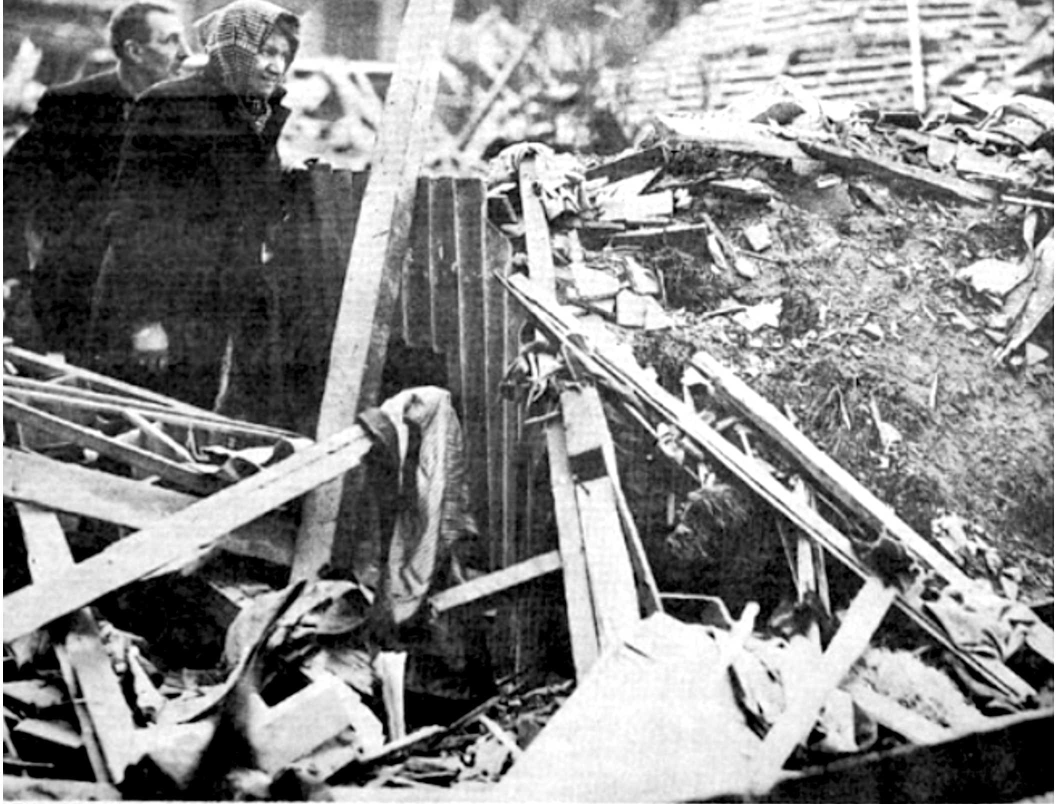


FIG. 3.—THE INDIVIDUAL PARTS.

And They Came Out of It Alive...

The edge of this bomb crater, 30ft. deep, in a household garden near London, is only 4ft. from the Anderson shelter. But the two people in the shelter during London's six-hour raid—Mrs. Clark and Miss Clark—were unhurt. You see Miss Clark in the picture examining the damage to the structure.

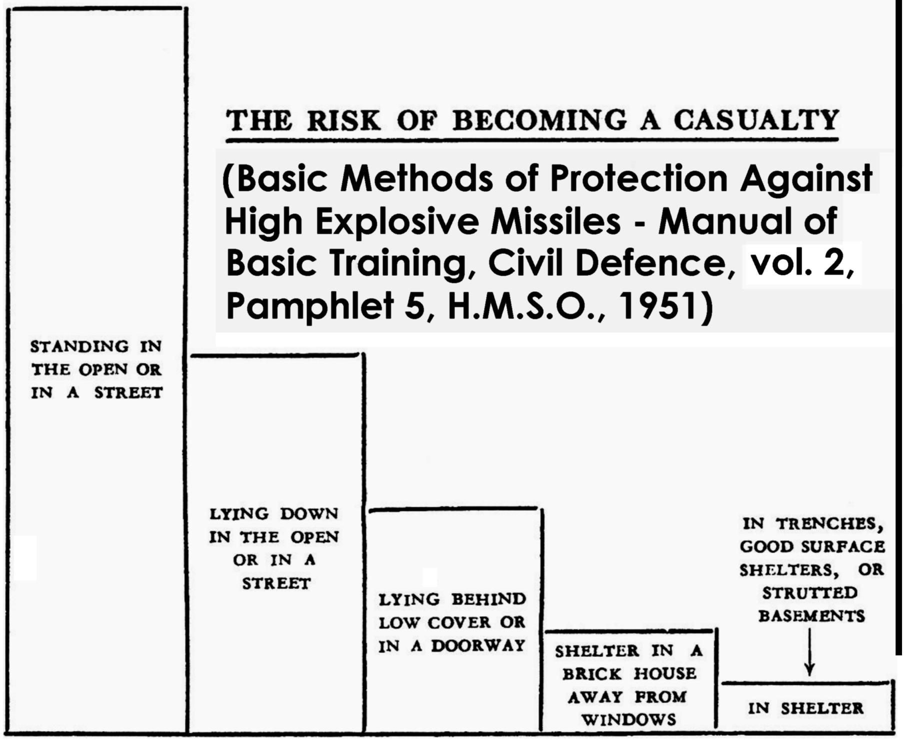
Daily Mirror
28 Aug 1940



Proof that the Anderson garden shelter could withstand a house collapsing on it can be seen in this picture. Mr. and Mrs. Clague bless their insistence on 'going to ground' when their homes and those of their neighbours were reduced to rubble.

18 June 1941

It cannot be too strongly emphasised that it is most important, from the point of view of reducing casualties as a whole, for everyone in an area under attack to make use of any shelter that is available. Recent research has shown that there would be less fatal casualties if everyone were in relatively poor shelter than if half the population were in shelter twice as good and the other half remained in the open.



(Basic Methods of Protection Against High Explosive Missiles - Manual of Basic Training, Civil Defence, vol. 2, Pamphlet 5, H.M.S.O., 1951)

Anderson shelters absorbed the blast energy and were damaged, saving lives.

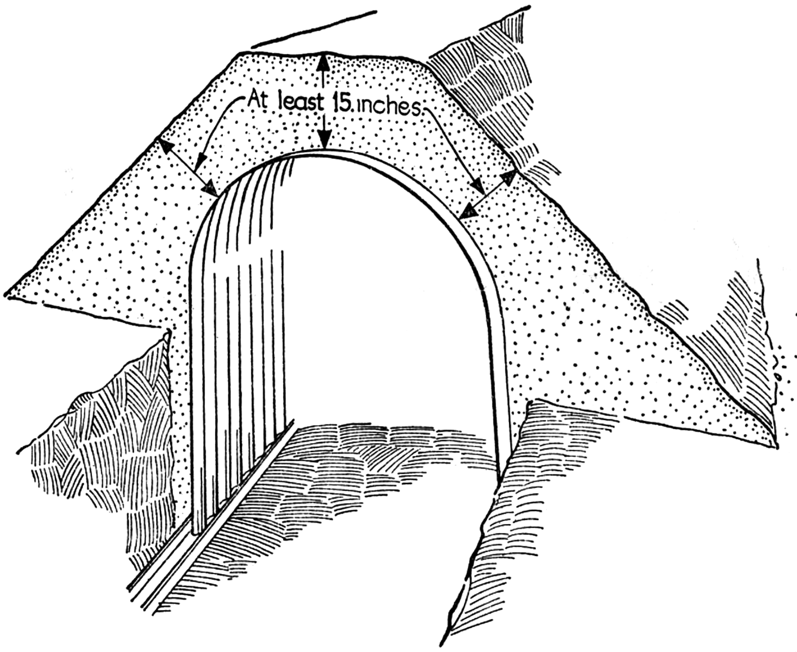


Fig. 4.—Stage 12. Covering the Shelter with Earth.

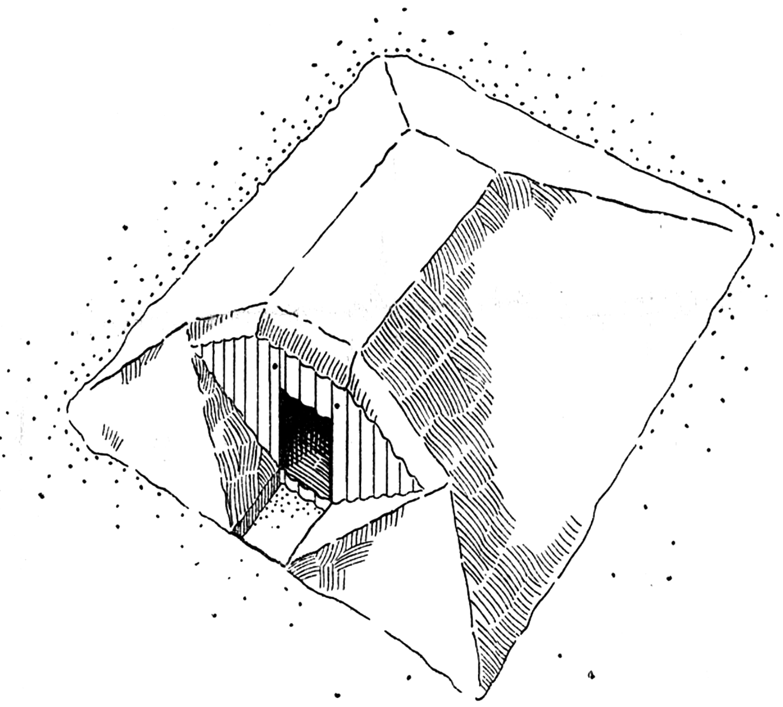


Fig. 4.—Stage 13. The Shelter Complete with Earth Cover.

Anderson shelter survives hit: Norwich 27 April 1942

THE EFFECTS OF THE ATOMIC BOMBS AT HIROSHIMA AND NAGASAKI

REPORT OF THE BRITISH MISSION TO JAPAN

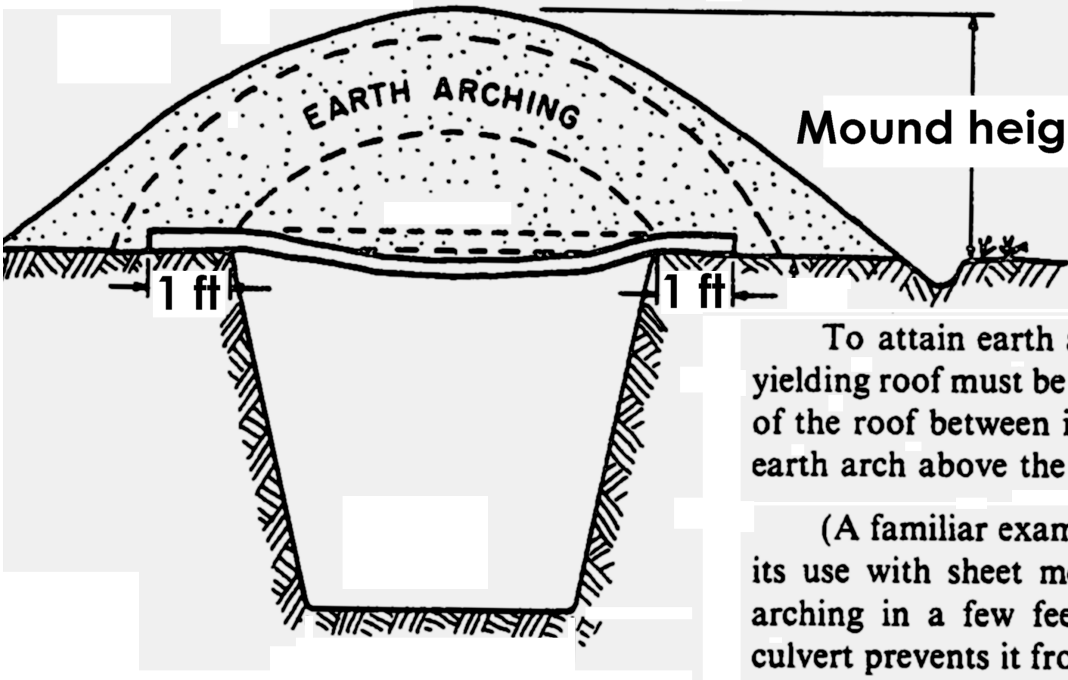
PUBLISHED
FOR THE HOME OFFICE AND THE AIR MINISTRY BY
HIS MAJESTY'S STATIONERY OFFICE
LONDON
1946

Photo No. 17. HIROSHIMA. Typical, part below ground, earth-covered, timber framed shelter 300 yds. from the centre of damage, which is to the right. In common with similar but fully sunk shelters, none appeared to have been structurally damaged by the blast. Exposed woodwork was liable to "flashburn." Internal blast probably threw the occupants about, and gamma rays may have caused casualties. See paragraph 40.

Photo No. 18. NAGASAKI. Typical small earth-covered back yard shelter with crude wooden frame, less than 100 yds. from the centre of damage, which is to the right. There was a large number of such shelters, but whereas nearly all those as close as this one had their roofs forced in, only half were damaged at 300 yds., and practically none at half a mile from the centre of damage. See paragraph 41.

EARTH ARCHING USED TO STRENGTHEN SHELTERS

(Source: C. H. Kearny, ORNL-5037)

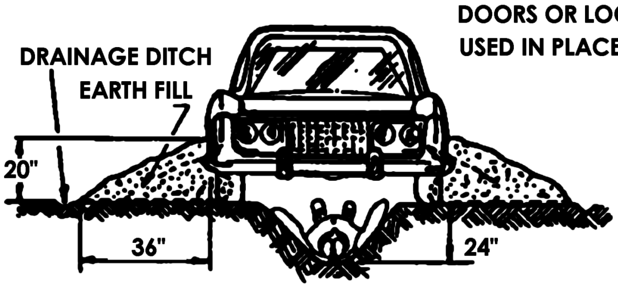


Mound height = half trench width (minimum)

To attain earth arching, the earth covering the yielding roof must be at least as deep as half the width of the roof between its supports. Then the resultant earth arch above the roof carries most of the load.

(A familiar example of effective earth arching is its use with sheet metal culverts under roads. The arching in a few feet of earth over a thin-walled culvert prevents it from being crushed by the weight of heavy vehicles.)

CAR-OVER-TRENCH FALLOUT SHELTER



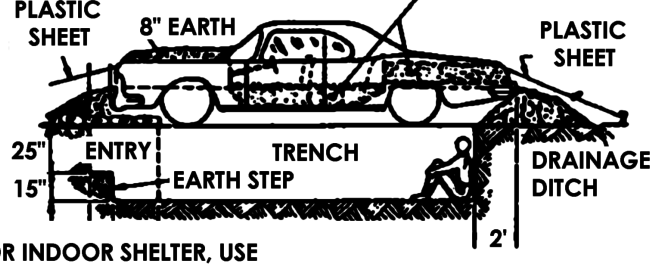
DOORS OR LOGS CAN BE USED IN PLACE OF CAR.

BANK EXCAVATED EARTH 20 INCHES HIGH AROUND CAR

PLACE 8" OF EARTH ON CAR HOOD

COVER FLOOR AND TRUNK WITH PLASTIC SHEET

PLACE 1 FOOT OF EARTH ON FLOOR AND TRUNK

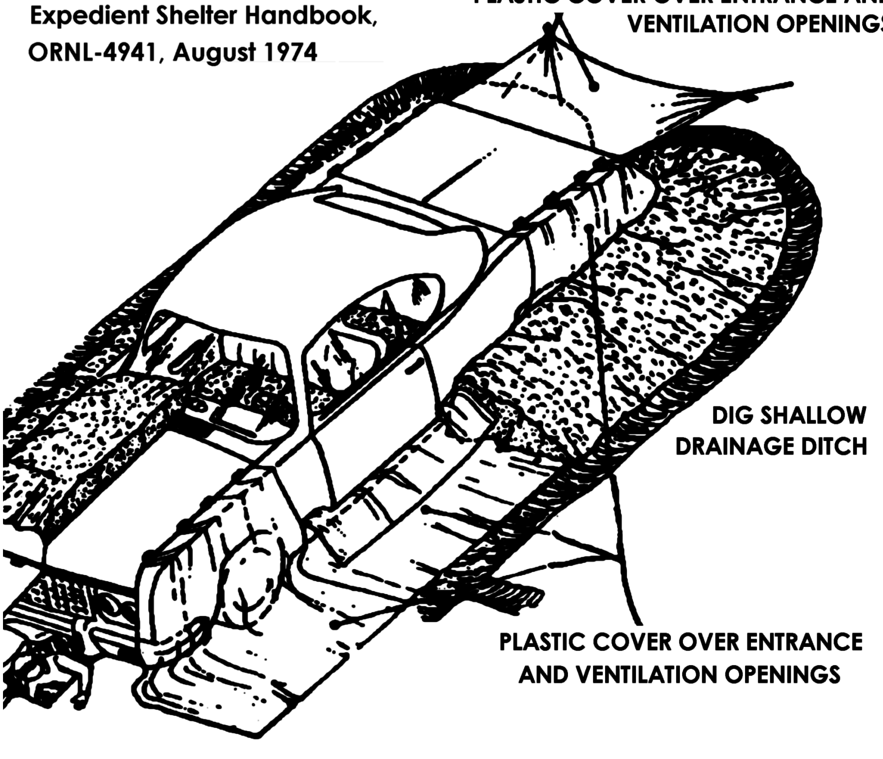


FOR INDOOR SHELTER, USE BAGS OF WATER INSIDE BOXES AROUND & ON TABLE

(CAR-OVER-TRENCH FIRST APPEARED IN "LOW-COST FAMILY SHELTERS," OCT. 1961 STANFORD RESEARCH INSTITUTE.)

G. A. Cristy and C. H. Kearny, Expedient Shelter Handbook, ORNL-4941, August 1974

PLASTIC COVER OVER ENTRANCE AND VENTILATION OPENINGS



DIG SHALLOW DRAINAGE DITCH

PLASTIC COVER OVER ENTRANCE AND VENTILATION OPENINGS

PLACE SAND-FILLED BAGS (SANDBAGS) AROUND ENTRANCE AND BANK EARTH AROUND THEM

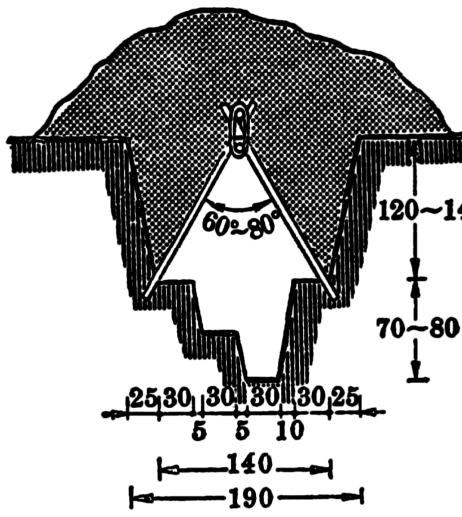


图 3-107 人字形骨架避弹所

CHINESE SHELTER SURVIVED 20 PSI PEAK OVERPRESSURE: THIN POLES WERE PROTECTED BY EARTH-ARCHING (DIMENSIONS IN CM.)

Source: C. H. Kearny, ORNL-5037

SECRET—GUARD

ANDERSON SHELTER TESTS AGAINST 25 KT NUCLEAR NEAR SURFACE BURST (2.7 METRES DEPTH IN SHIP)

DEPARTMENT OF ATOMIC ENERGY

ATOMIC WEAPONS RESEARCH ESTABLISHMENT
(formerly of Ministry of Supply)

SCIENTIFIC DATA OBTAINED AT OPERATION HURRICANE
(Monte Bello Islands, Australia—October, 1952)

DIRECTOR'S REPORT

Summary

This report summarises data on the external effects observed in the trial of the first British atomic weapon, which was exploded under conditions representing a ship-borne attack on a port.

Briefly, it may be said, in reviewing the general physical effects, that the air blast and gamma flash effects were comparable with those for an air burst but the thermal radiation effects were very much less. The underwater shock was much less than that from an underwater burst. Some general information on the residual contamination is given, but data on the extent of the contamination forms the subject of a separate section not generally available.

The report describes the conditions under which the trial was conducted, the measurements made of the physical phenomena produced by the detonation of the weapon, and gives brief descriptions of the results.

Information is given concerning the behaviour of Anderson shelters, of certain reinforced concrete cubicles, of a model ship's funnel, of a compartment representing a deckhouse, and various aircraft components. Data are also given for the penetration of gamma rays into slit trenches, concrete cubicles and Anderson shelters; for the effect of thermal radiation on various materials and service equipment; and for possible contamination (and decontamination) of personnel, equipment, ships and food stored in open dumps. The report also includes the results of experiments on the absorption of radio-elements by biological systems.

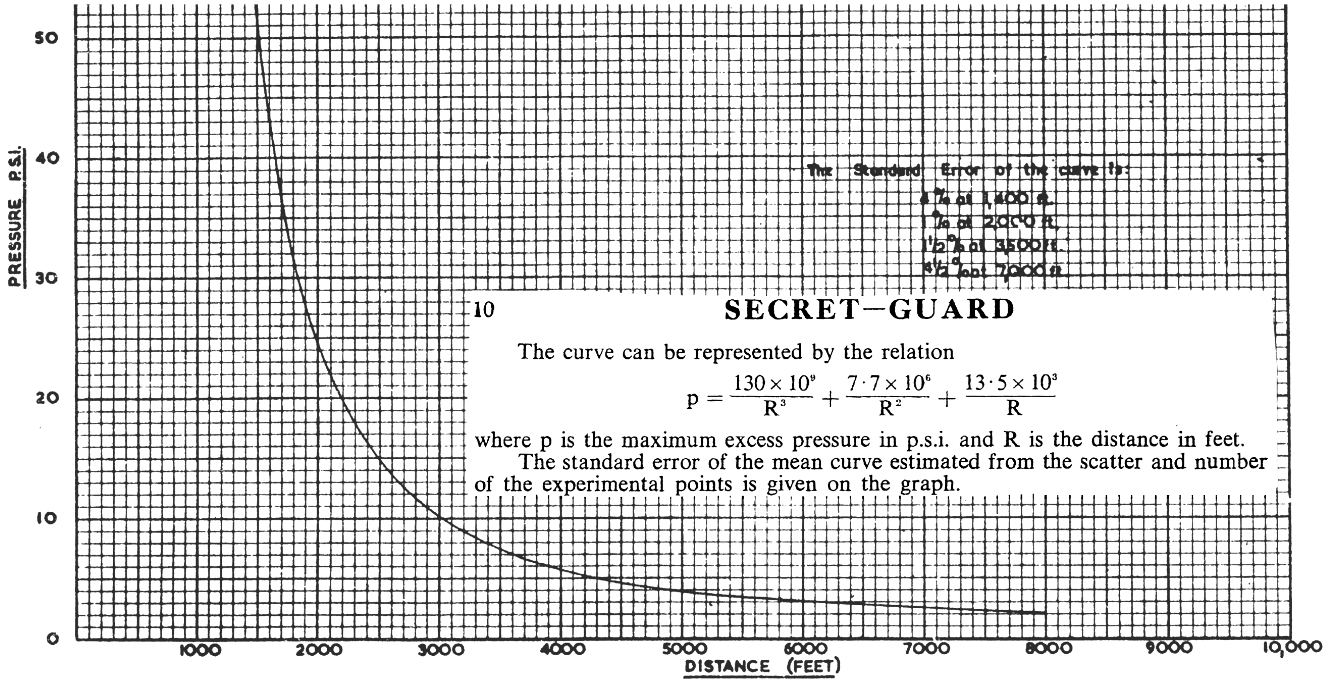
Regraded by A.W.R.E. on ....10-1-61.......

From SECRET ATOMIC GUARD

to SECRET

UK NATIONAL ARCHIVES: ES 5/2

(Atomic Weapons Research Est. report AWRE-T1/54, 27 Aug. 1954)



10 **SECRET—GUARD**

The curve can be represented by the relation

$$p = \frac{130 \times 10^9}{R^3} + \frac{7 \cdot 7 \times 10^6}{R^2} + \frac{13 \cdot 5 \times 10^3}{R}$$

where p is the maximum excess pressure in p.s.i. and R is the distance in feet.

The standard error of the mean curve estimated from the scatter and number of the experimental points is given on the graph.

25 kt nuclear trial (Monte Bello, 3 October 1952)

Fig. 12.1, Andersons at 1380 ft range from bomb ship shown in the photo, moored 400 yards off shore.

Left: Fig. 12.3, Andersons at 1800 ft after burst. Right: Fig. 12.4, Andersons protected by blast walls at 2760 ft.

SANDBAGS GIVE
NO "EARTH ARCHING"
PROTECTION
(WORST CASE)

12. Blast Effects

12.1. *Blast Damage to Anderson Shelters*

12.1.1. In accordance with certain requirements of the Chief Scientific Adviser to the Home Office, fifteen Anderson shelters were erected, three at each of five sites situated, on Trimouille Island, more or less due West of the explosion at distances of 1,380, 1,530, 1,800, 2,760 and 3,390 feet. In each group one shelter was placed with its entrance facing the explosion, one with the entrance facing away from the explosion and one sideways to it.

The shelters were erected with a blast wall shielding the entrance, by the normal procedure laid down by the Ministry of Works, there being a difference from the usual practice in this country in that the covering of the shelter and the filling of the blast wall, instead of being earth, consisted of sandbags filled with fine dune sand, the only material available. The shelters were sunk with their floors about 4 feet below ground level; the thickness of the sandbags averaged 18 inches directly over the top of the roof arch to about 3 ft. 6 ins. at ground level at the sides. The blast wall was from 2 ft. to 2 ft. 6 ins. thick contained within sheets of corrugated iron and was placed about 3 feet from the shelter.

12.1.2. In the groups of shelters at 1,380, 1,530 and 1,800 feet, the sandbags covering them were almost entirely blown away and the blast walls were destroyed.

At 1,380 feet, Fig. 12.1, parts of the main structure of the shelters facing towards and sideways to the explosion were blown in but the main structure of the one facing away from the explosion was intact, and would have given full protection. At 1,530 feet, Fig. 12.2, the front sheets of the shelter facing the explosion were blown into the shelter but otherwise the main structures were more or less undamaged, as were those at 1,800 feet, Fig. 12.3.

At 2,760 feet, Fig. 12.4, some of the sandbags covering the shelters were displaced and the blast walls were distorted whilst at 3,390 feet, Fig. 12.5, the effect was quite small. At these distances, the shelters were not in direct view of the explosion owing to intervening sandhills.

13. The Penetration of the Gamma Flash

13.1. *Experiments on the Protection from the Gamma Flash afforded by Slit Trenches*

13.1.1. The experiments described in this section show that slit trenches provide a considerable measure of protection from the gamma flash. From the point of view of Service and Civil Defence authorities this is one of the most important results of the trial.

13.1.2. Rectangular slit trenches 6 ft. by 2 ft. in plan and 6 ft. deep were placed at 733, 943 and 1,300 yards from the bomb and circular fox holes 2 ft. in radius and 6 ft. deep were placed at 943 and 1,300 yards.

The doses received from the flash were measured with film badges and quartz-fibre dosimeters in order to determine the variation of protection with distance, with depth and with orientation of the trench and the relative protection afforded by open and covered trenches.

In general, the slit trenches were placed broadside-on to the target vessel but at 1,300 yards one trench was placed end-on. Two trenches, one at 733 and one at 943 yards were covered with the equivalent of 11 inches of sand.

Table 13.1

Variation of Gamma Flash Dose on Vertical Axis of Trench

Type of trench	Rectangular broadside-on open			Rectangular end-on open	Circular open		Rectangular broadside-on covered	
Distance (yards) ...	1,300	943	733	1,300	1,300	943	943	733
Surface dose (Roentgens)	300	3,000	14,000	300	300	3,000	3,000	14,000
Depth below ground level (inches)								
6 ...	150	1,000	—	230	214	1,200	(75)	—
12 ...	75	430	—	150	120	545	47·6	—
24 ...	33·3	150	584	60	54·5	188	25	(140)
36 ...	23	70	216	31·6	30	86	13	(56)
48 ...	(20)	43	100	20	17·7	48·5	7·7	(31)
60 ...	—	(37·5)	61	13·6	10·7	(33·3)	5	(23)
72 ...	—	—	(46·7)	(8·6)	7	—	(3·5)	—

Entries in brackets are extrapolations or estimates.

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W... 22/10/84 . SCO 468 refers

NATIONAL ARCHIVES
ES5/1

MINISTRY OF SUPPLY

ATOMIC WEAPONS RESEARCH ESTABLISHMENT

REPORT No. T 1/53
(HURRICANE)

B. 0134

DECLASSIFIED FOR PR...
BY AWE ALDERMASTON...

~~TOP SECRET~~

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A.W.R.E.
Aldermaston Berks.

[redacted]

May, 1953

3.2 Blast Damage

3.2.1 Anderson Shelters

Standard Anderson Shelters, with sandbag covering and blast wall construction were locat.:d at 460, 510, 600, 920 and 1,130 yards from ground zero. Mean blast pressures, in pounds/sq. inch, recorded inside the shelters are shown in the following table.

Distance (yds.)	Presentation		
	Front	Side	Rear
460	NR	NR	NR
510	38	27	40
600	28	21	28
920	16	7	14
1130	8.5	4	5.5

Front presentation implies blast wall facing towards event.
Rear " " " " " away from event.
Side " " shelter side on to event.

Shelters at 460, 510 and 600 yards suffered damage including demolition of blast walls, removal of sandbag covering and some displacement of the corrugated iron.

At 920 and 1,130 yards the shelters suffered relatively little damage.

Civil defence authorities consider that there might have been some 50% survival from blast damage of personnel in shelters at 460 yards and some 90 per cent at 600 yards, fatal casualties being mainly due to secondary blast effects (e.g. debris) and not to direct effects on the person of the blast pressure itself. The front presentation appears the most hazardous, due to the collapse of the blast wall into the shelter. At such distances, however, the survival from the effects of gamma flash would have been virtually nil. (MORE EARTH COVER IS NEEDED FOR RADIATION.)

At 920 and 1,130 yards there would have been no casualties from blast, and incidentally, little risk from the effect of gamma flash.

The Effects of

Nuclear Weapons

SAMUEL GLASSTONE
Editor

Prepared by the

UNITED STATES DEPARTMENT OF DEFENSE

Published by the

UNITED STATES ATOMIC ENERGY COMMISSION

June 1957

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price $2.00 (paper bound)

TABLE 3.11

OVERPRESSURE, DYNAMIC PRESSURE, AND WIND VELOCITY IN AIR AT SEA LEVEL

Peak overpressure (pounds per square inch)	*Peak dynamic pressure (pounds per square inch)*	*Maximum wind velocity (miles per hour)*
72	80	1, 170
50	40	940
30	16	670
20	8	470
10	2	290
5	0. 7	160
2	0. 1	70

3.12 At a given location, the dynamic pressure changes with time in a manner somewhat similar to the change in the overpressure, but the rate of pressure decrease behind the shock front is different. This may be seen from Fig. 3.12 which indicates qualitatively how the two pressures vary in the course of the first second or so following arrival of the shock front.

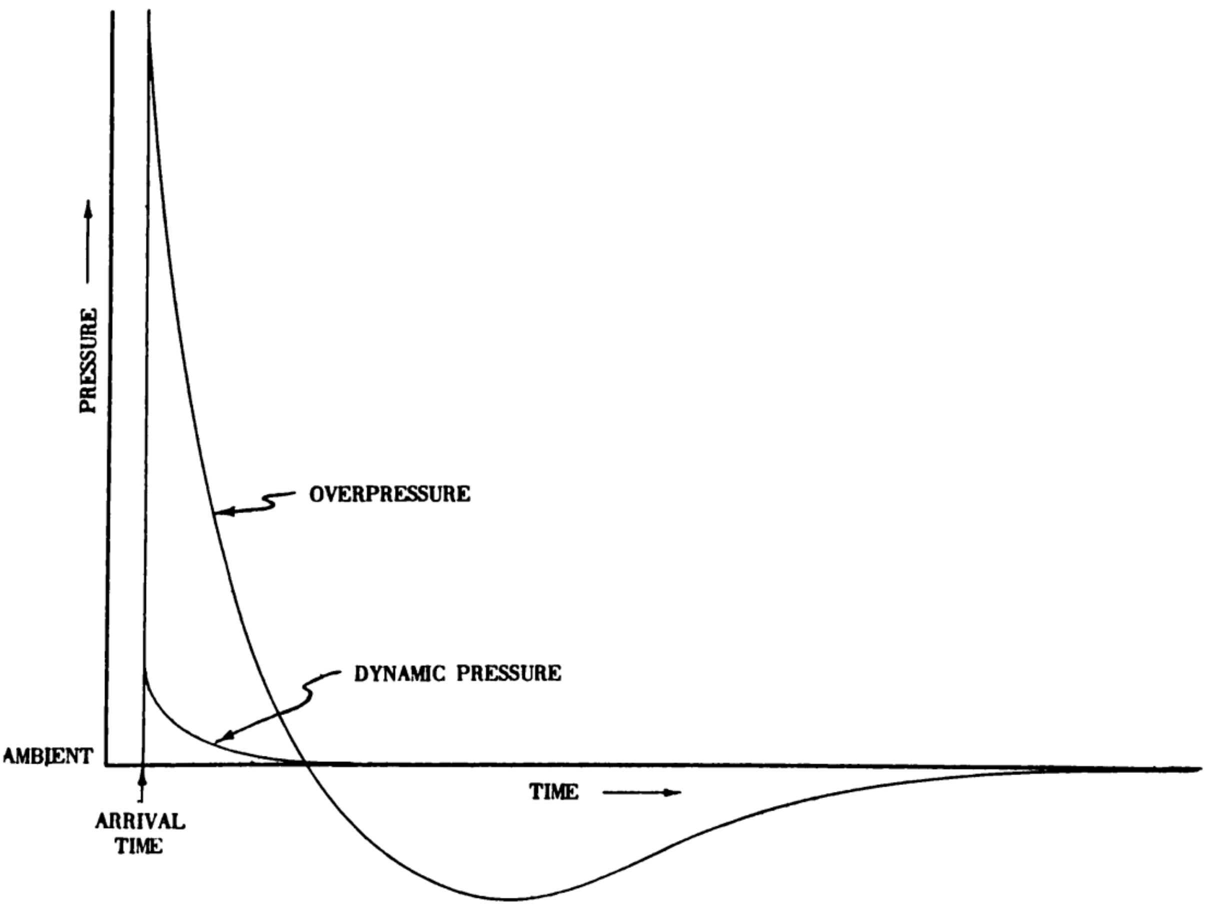


Figure 3.12. Variation of overpressure and dynamic pressure with time at a fixed location.

The curves show the variation of peak overpressure with distance for a 1 KT surface burst and for a 1 KT free-air burst (based on the $2W$ assumption in § 3.94) in a standard sea level atmosphere.

Scaling. For yields other than 1 KT, the range to which a given overpressure extends scales as the cube root of the yield, i. e.,

$$d = d_0 \times W^{1/3},$$

where, for a given overpressure,

d_0 is the distance from the explosion for 1 KT,

and

d is the distance from the explosion for W KT.

Example

Given: A 1 MT surface burst.

Find: The distance to which 2 psi extends.

Solution: From Fig. 3.93 the cube root of 1000 is 10. From Fig. 3.94a, a peak overpressure of 2 psi occurs at a distance of 0.53 mile from a 1 KT surface burst. Therefore, for a 1 MT surface burst,

$$d = d_0 \times W^{1/3} = 0.53 \times 10 = 5.3 \text{ miles.} \quad \textit{Answer}$$

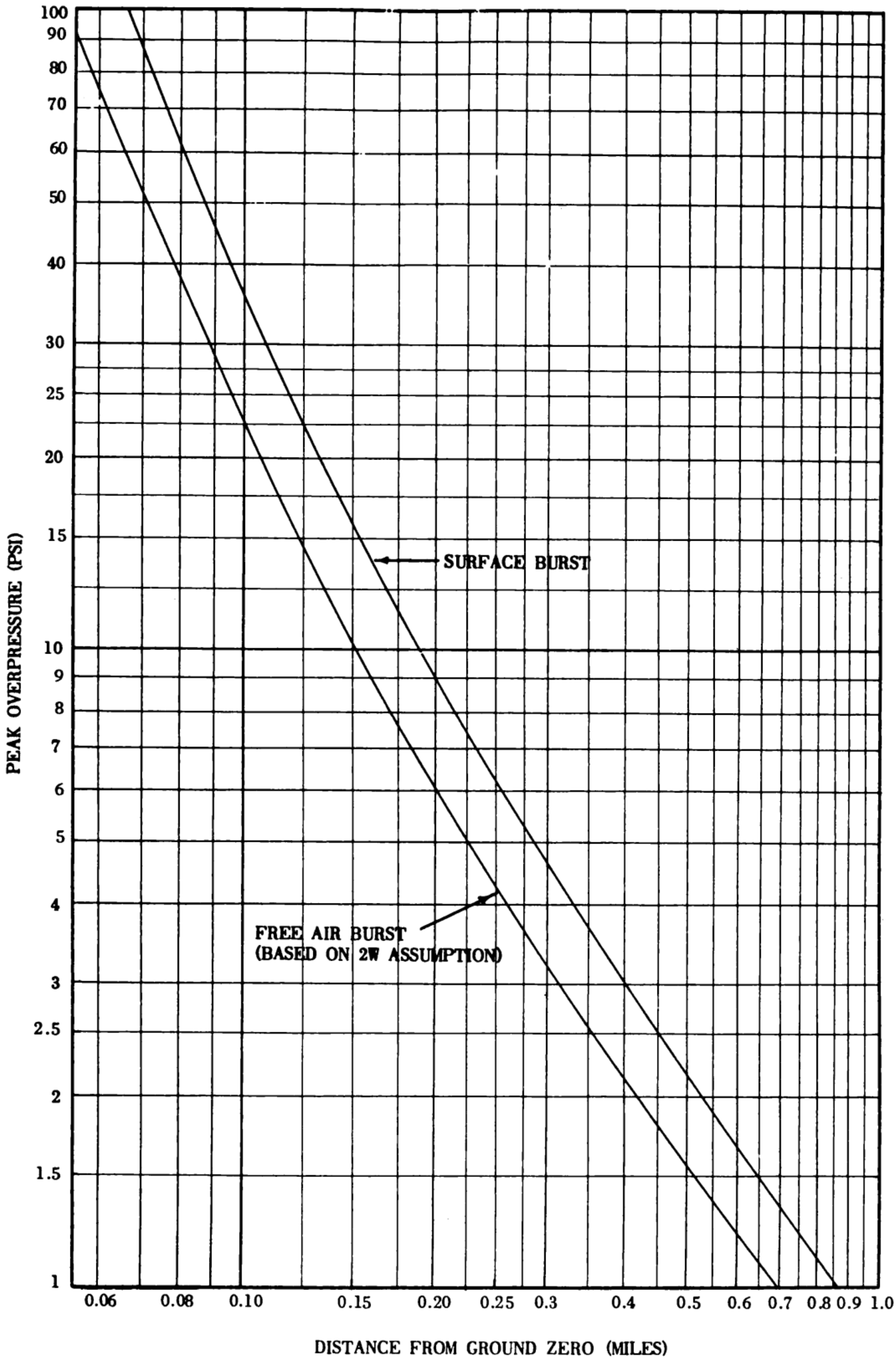


Figure 3.94a. Peak overpressure for a 1-kiloton surface burst and free air burst.

TABLE 6.12

DAMAGE CRITERIA FOR SHALLOW BURIED OR EARTH COVERED SURFACE STRUCTURES

Type of structure	Damage class	Peak over-pressure (psi)	Nature of damage
Light, corrugated steel arch, surface structure (10-gage corrugated steel with a span of 20 to 25 feet) with 3 feet of earth cover over the crown.	A	35–40	Complete collapse.
	B	30–35	Collapse of portion of arch facing blast.
	C	20–25	Deformation of end walls and arch, possible entrance door damage.
	D	10–15	Possible damage to ventilation system and entrance door.
Light, reinforced-concrete surface or underground shelter with 3 feet minimum earth cover. (Panels 2 to 3 inches thick, with beams spaced on 4-foot centers.)	A	30–35	Collapse.
	B	25–30	Partial collapse.
	C	15–25	Deformation, severe cracking and spalling of panels.
	D	10–15	Cracking of panels, possible entrance door damage.

6.13 An illustration of B-type damage to a 10-gage corrugated steel-arch, earth-covered, surface structure is shown in Fig. 6.13. It will be noted that about half of the arch has collapsed. This failure was attributed primarily to the dynamic pressure acting on the forward slope of the earth mound.

6.14 The peak overpressure for the complete collapse of the corrugated steel-arch structure, with 3 feet of earth cover, is given in Table 6.12 as 35 to 40 pounds per square inch. However, it has been estimated that if this structure had been completely buried, so that no earth mound was required, an overpressure of 40 to 50 pounds per square inch would have been necessary to cause it to collapse. This increase in the required overpressure is due to the fact that the dynamic pressure is minimized under these conditions. It may be mentioned

Figure 6.13. B-type damage to earth-covered 10-gage corrugated steel structure.

that, using standard engineering techniques, it is possible to design underground structures which will withstand blast overpressures in excess of 100 pounds per square inch at the surface (see Chapter XII).

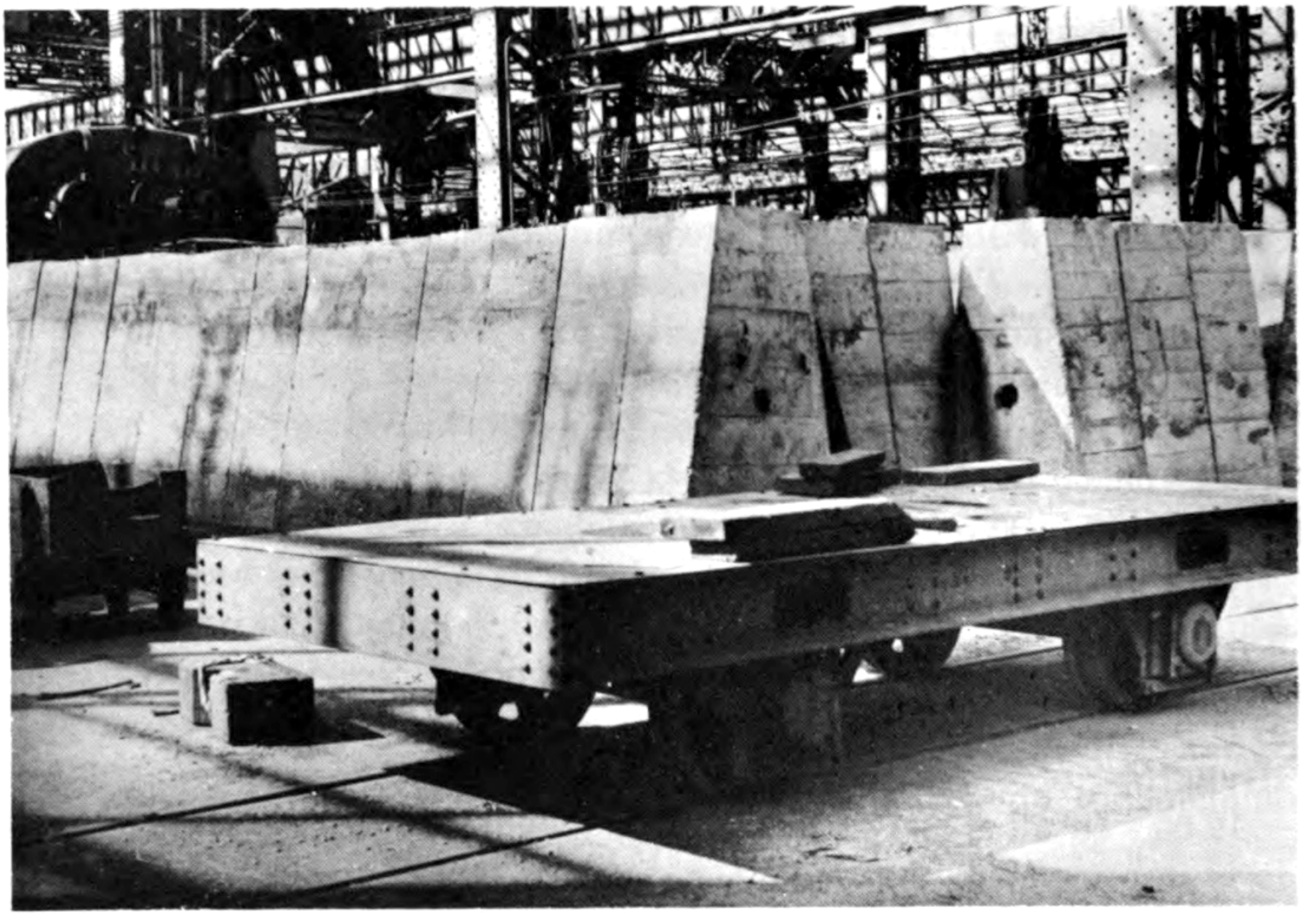


Figure 12.37a. Precast, reinforced-concrete blast walls (0.85 mile from ground zero at Nagasaki).

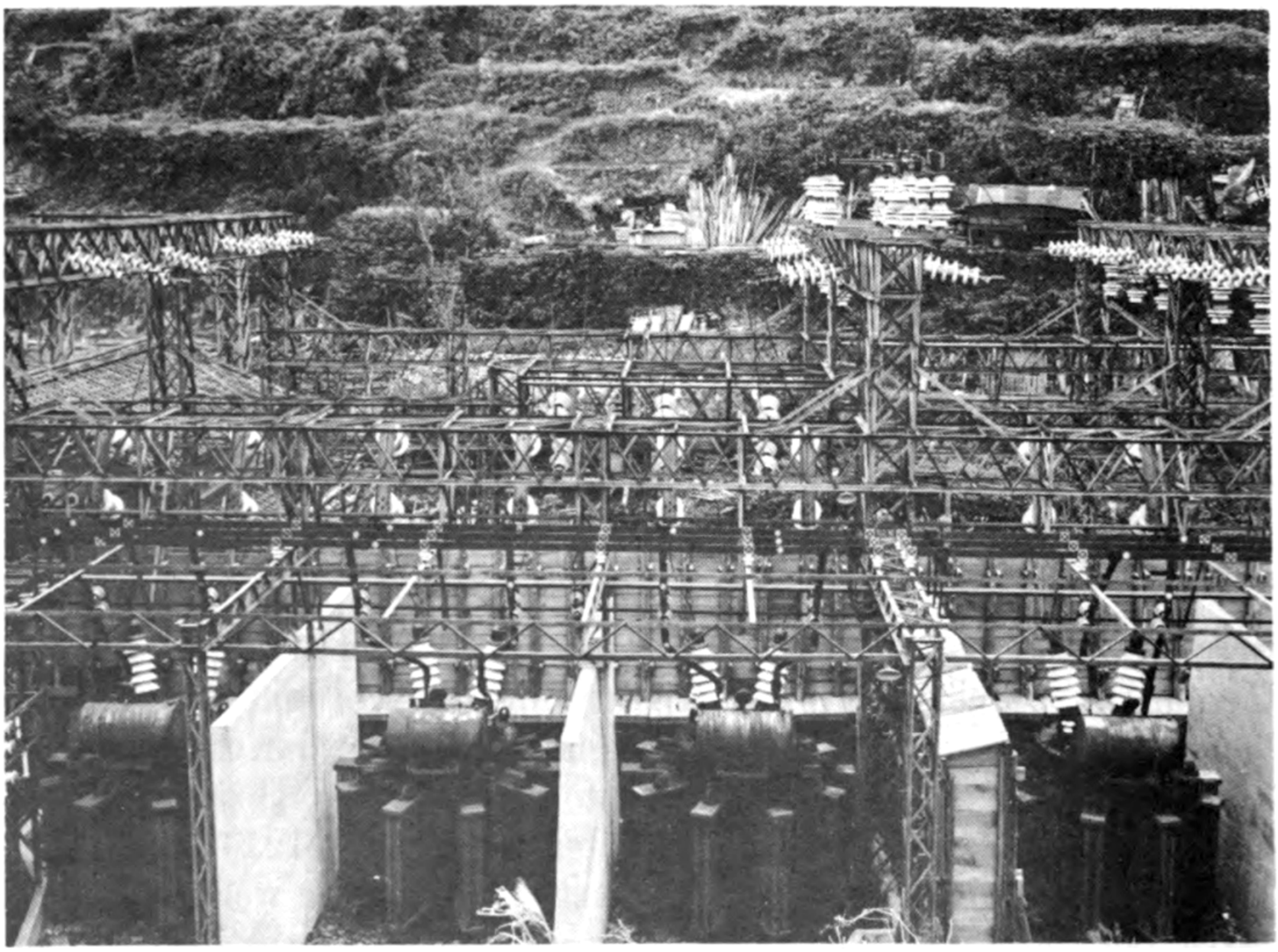


Figure 12.37b. Reinforced-concrete blast walls protecting transformers (1 mile from ground zero at Nagasaki).

WHEN YOU GO TO SHELTER

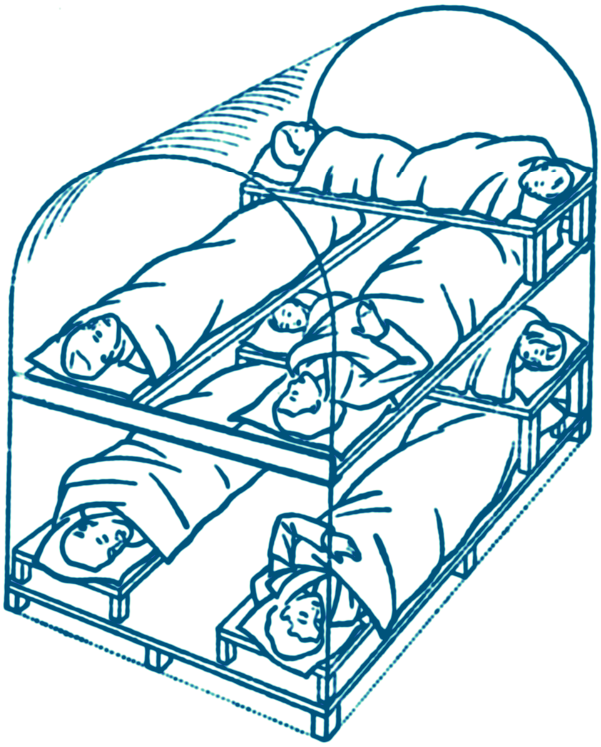
Your Anderson shelter this Winter

1940

ISSUED BY THE MINISTRY OF HOME SECURITY

BY FAR THE BEST bedding for any shelter is a properly made sleeping bag. Nothing else can give so much warmth.

Take any Army or similar thick blanket about 7 ft. long and 6½ ft. wide (or pieces of old blankets could, of course, be joined together). Line with muslin or cotton material to within a short distance of the top. Sew straight across both blanket and lining horizontally at intervals of about a foot, making pockets which should be well stuffed with folded newspaper. The newspaper stuffing should be changed every month.



HOW TO MAKE BUNKS

Look at the diagram of the arrangement of bunks and you will at once see the idea. The top bunks run from one end of the shelter to the other, the ends resting on the angle-irons that run horizontally across the shelter at each end. These bunks should be 20 in. wide, and about 6 ft. 6 in. long.

The cross bunks for the children are 4 ft. 6 in. long, and have four legs, each 14 in. high, which rest on the side pieces of the lengthways bunks.

SECRET.

W.P.(G)(41)7. COPY NO. 62

January 15th, 1941.

WAR CABINET.

AIR RAID SHELTER POLICY.

Memorandum by the Minister of Home Security.

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6. Shelter in the home: The Anderson shelter was originally intended for indoor use but for a number of reasons including the danger of fire an outdoor variant was adopted. Experience has shown that the objections to the indoor use of the Anderson or somewhat similar shelter are not so serious as was thought and two designs have been produced which can be erected indoors without support. These new types, although they may give slightly less protection than a well covered Anderson shelter out of doors, would fill the needs of a large section of the public, especially the middle class. One design allows the use of the shelter as part of the furniture of the room.

7. I regard shelters of this type as of the first importance and wish to provide them on a big scale. Each shelter will use over 3 cwt. of steel and will allow at a pinch two adults and one to two children to sleep inside. For an outlay of about 65,000 tons of steel, as a first instalment, I could therefore produce 400,000 shelters with accommodation for at least 1,000,000 persons. I should wish to complete such a programme within the first three months of production and thereafter at a similar or increasing rate. From enquiries I believe that manufacture can be arranged provided steel is supplied and if the Cabinet approves my policy I shall require their direction that the steel be made available.

10. Conclusions.

I ask for a general endorsement of the policy I have outlined in this paper and in particular for the agreement of my colleagues:

(i) that proposals for building shelters of massive construction should be rejected;

(ii) that steel should be made available to carry out the programme outlined in paragraph 7 for the provision of steel shelters indoors;

(iii) that the limit of income for the provision of free shelter for insured persons should be raised from £250 to £350 per annum.

H.M.

MINISTRY OF HOME SECURITY.
January 15th, 1941.

November 1940 design by C. A. Joy, M. Inst. Me. & C. E., Bexley Borough Engineer (UK National Archives: HO 205/257)

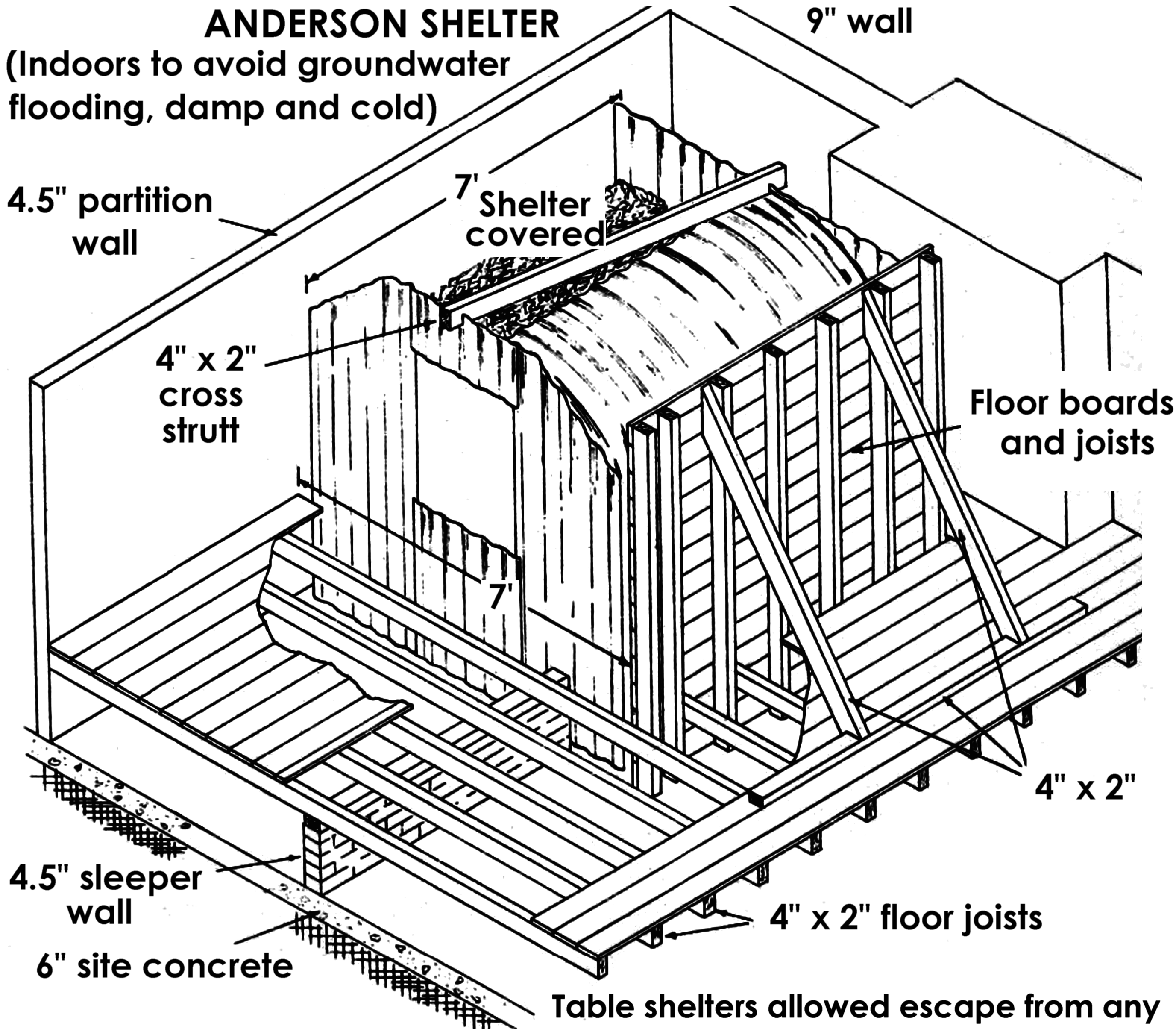
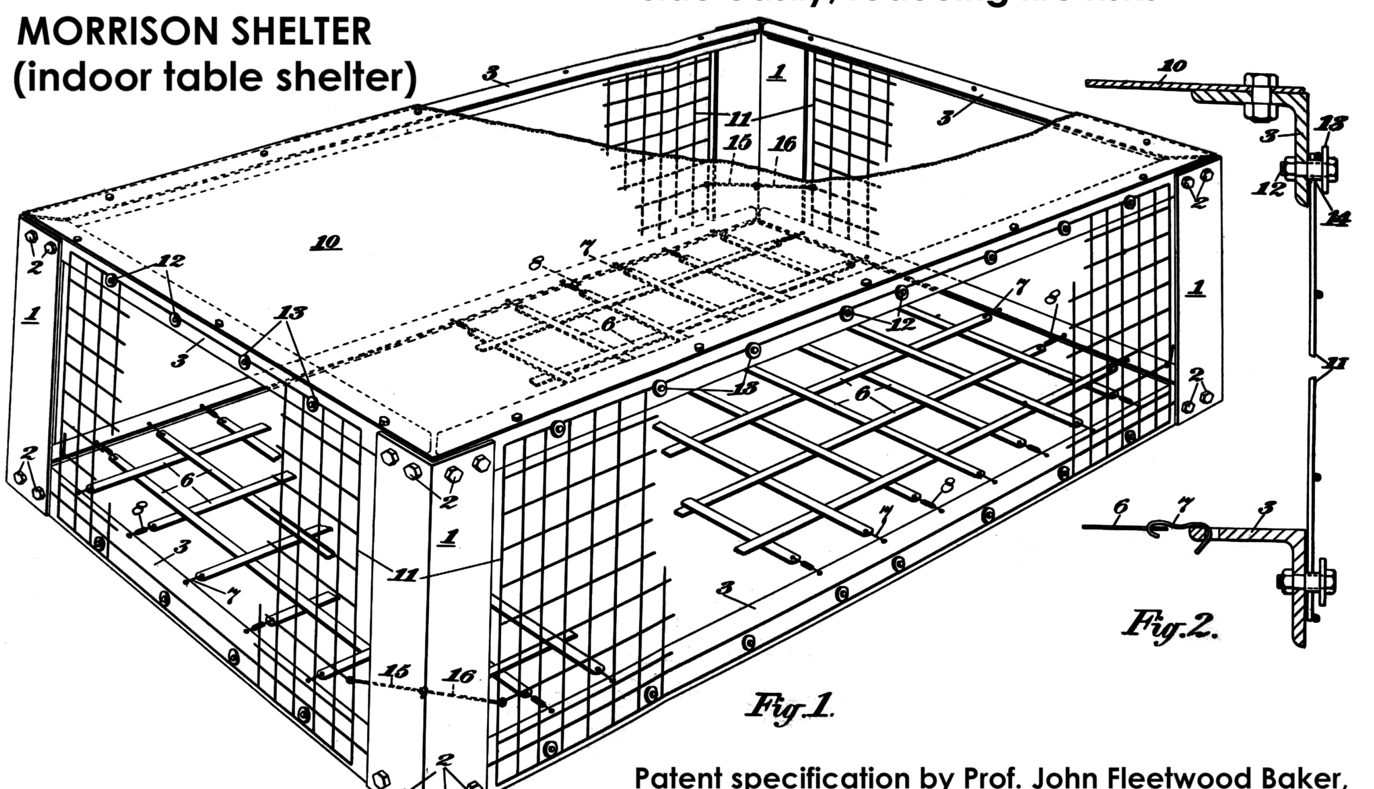
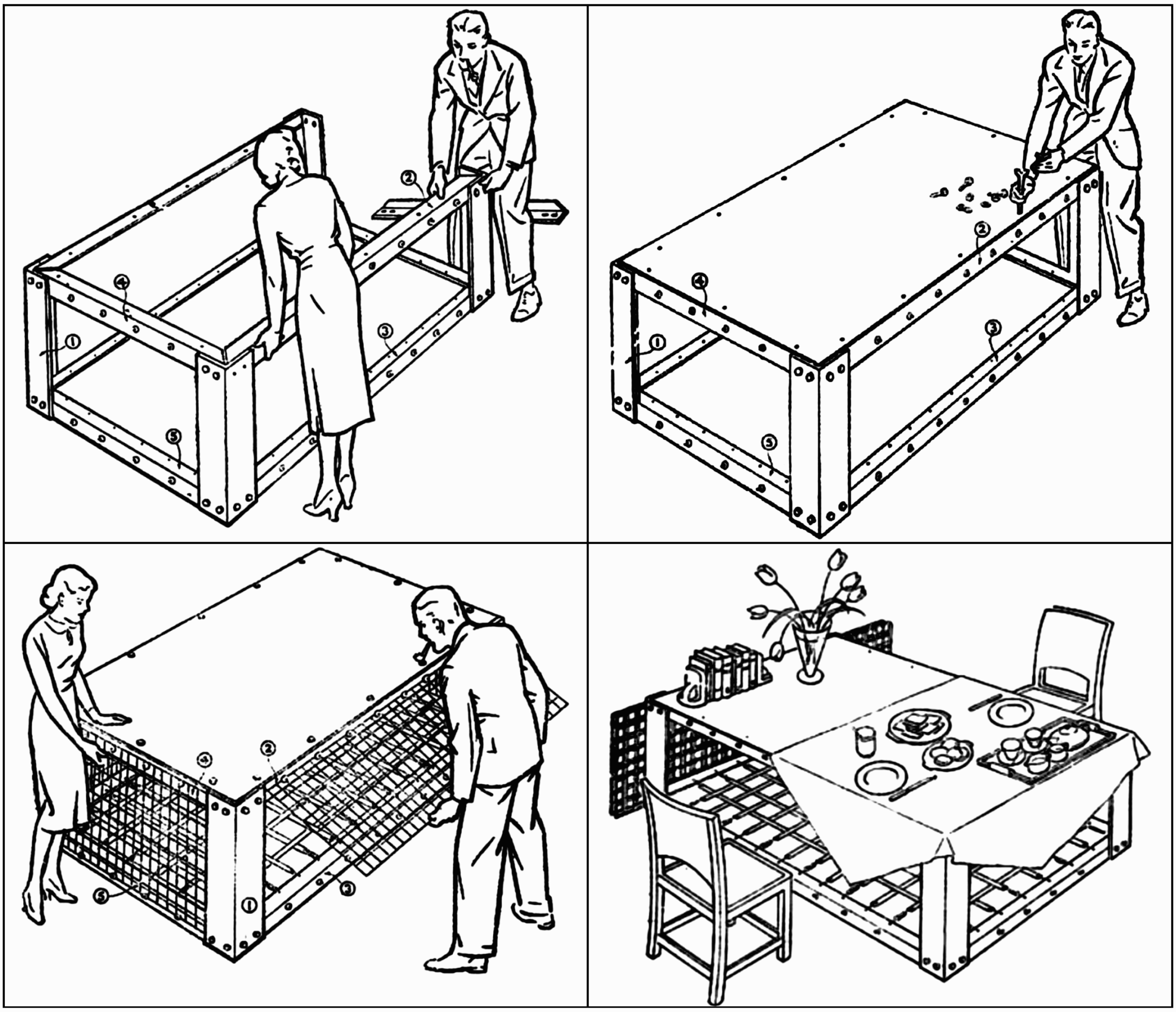
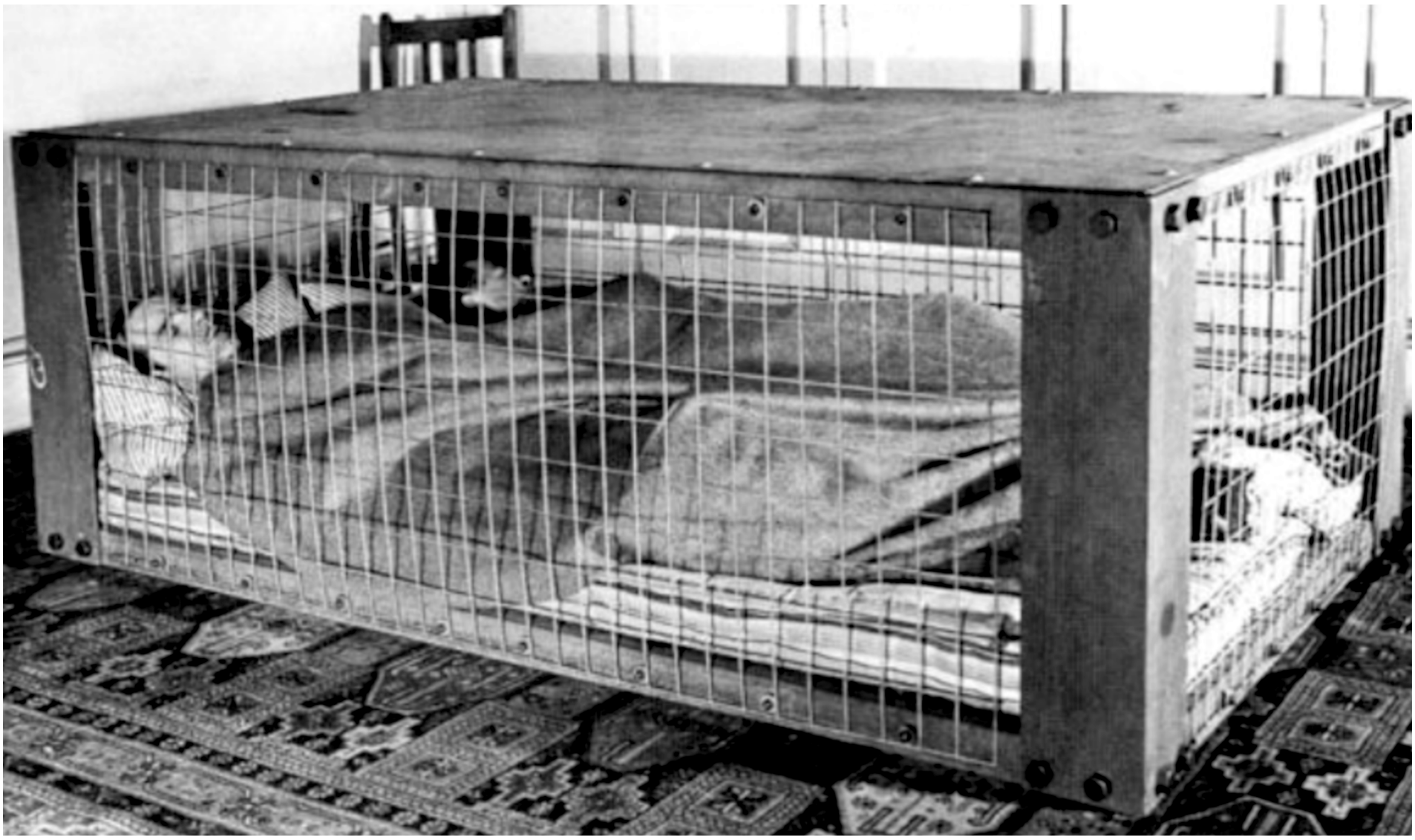


Table shelters allowed escape from any side easily, reducing fire risks



Patent specification by Prof. John Fleetwood Baker, Ministry of Home Security (National Archives HO 356/10)

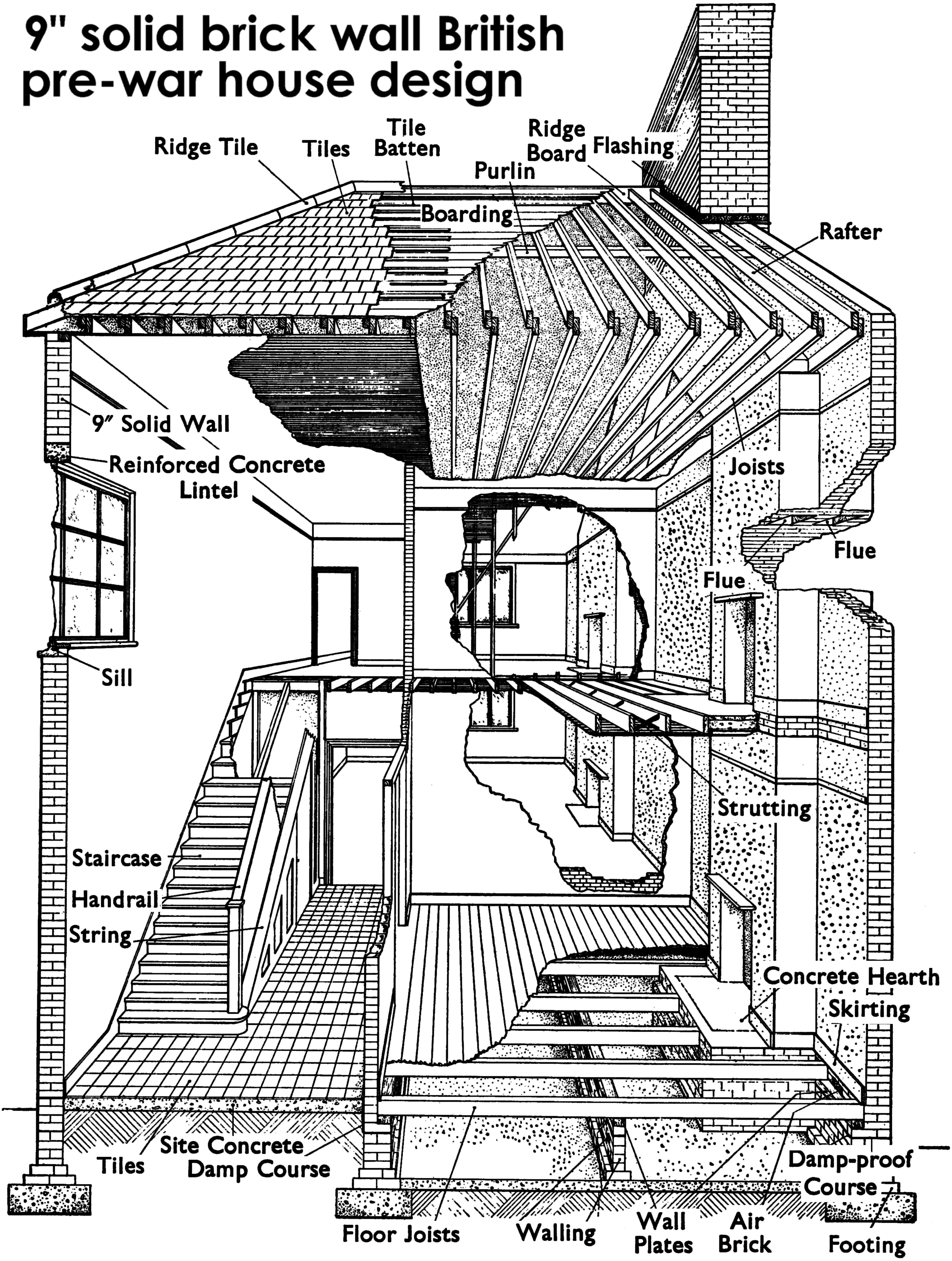




Structural Defense, 1945, by D. G. Christopherson, Ministry of Home Security, RC 450, (1946); Chapters VIII and IX (Confidential). Chapter VIII summarizes the literature on the design and types of British shelters and analyzes their effectiveness.

National Archives HO 195/16

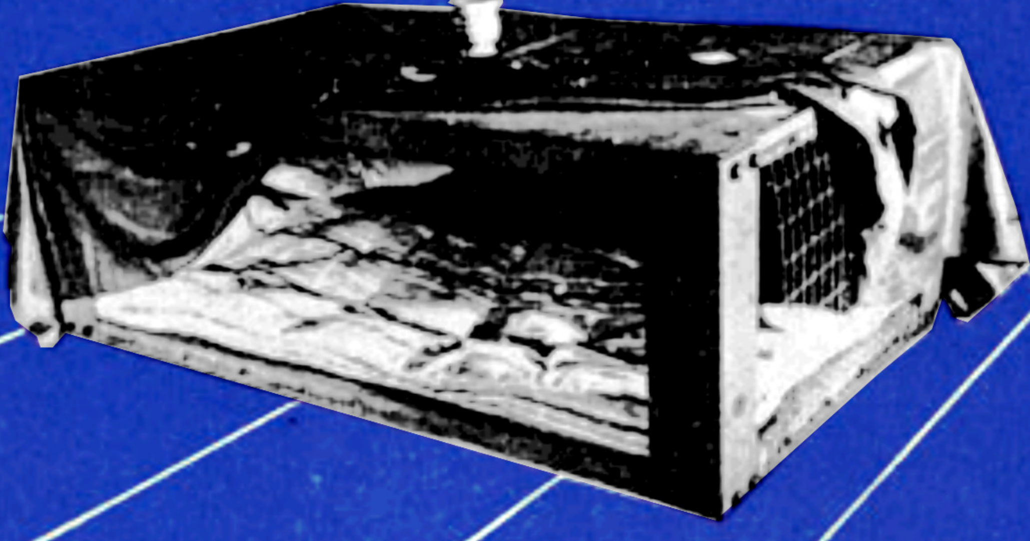
9" solid brick wall British pre-war house design







SHELTER at home



3d. ISSUED BY THE MINISTRY OF HOME SECURITY AND PUBLISHED BY H.M. STATIONERY OFFICE

ILLUSTRATION NO. 8.

The house in the upper photograph had a Government steel table shelter in a downstairs room and was blown up to reproduce the effect of a heavy bomb falling near. The whole house collapsed, burying the shelter under débris. In the lower photo the shelter can be seen still intact. It would have been possible for anyone in the shelter to get out unaided.

(Page 11 from the June 1941 UK Ministry of Home Security "Shelter at Home" handbook.)

Morrison shelter survives direct hit in York 1942

Morrison Shelters in Recent Air Raids.

A report of Ministry of Home Security experts on 39 cases of bombing incidents in different parts of Britain covering all those for which full particulars are available in which Morrison shelters were involved shows how well they have stood up to severe tests of heavy bombing.

All the incidents were serious. Many of the incidents involved direct hits on the houses concerned a risk against which it was never claimed these shelters would afford protection. In all of them the houses in which shelters were placed were within the radius of damage by bombs; in 24 there was complete demolition of the house on the shelter.

A hundred and nineteen people were sheltering in these "Morrisons" and only four were killed. So that 115 out of 119 people were saved. Of these only 7 were seriously injured and 14 slightly injured while 94 escaped uninjured. The majority were able to leave their shelters unaided.

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CD/SA 12
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HOME OFFICE

OFFICE OF THE CHIEF SCIENTIFIC ADVISER

A COMPARISON BETWEEN THE NUMBER OF PEOPLE KILLED PER TONNE OF BOMBS DURING WORLD WAR I AND WORLD WAR II

BOMB SIZES

=> ≈ 175 kg

For World War II the average bomb weight was between 150 - 200 kg. (R.C. 268, Table 6), whereas for World War I the majority of bombs were 12 or 50 kg.

TABLE 5

Relative safeties in World War II deduced from population and casualty distribution

	In the open	Under cover	In shelter
Population exposure	5%	60%	35%
Location people killed	19%	62%	19%
Relative safety RELATIVE DANGER!	72%	20%	10%

(1) A house about $3\frac{1}{2}$ times as safe as in the open.
(2) A shelter about twice as safe as a house.

Table 6 also shows the location of killed which is implied by each of the possible population exposures. The only evidence available on this point is that, for the day raid on June 13th, 1916, in which the total number killed was 59, 69.5% of the people killed in the City were in the open.

UK NATIONAL ARCHIVES: HO225/16 (1950)

THE NUMBER OF ATOMIC BOMBS EQUIVALENT TO THE LAST WAR AIR ATTACKS ON GREAT BRITAIN AND GERMANY

Summary

During the last war, a total of 1,300,000 tons* of bombs were dropped on Germany by the Strategic Air Forces. If there were no increase in aimi accuracy, then to achieve the same total amount of material damage (to houses, industrial and transportation targets, etc.) would have required the use of over 300 atomic bombs together with some 500,000 tons of high explosive and incendiary bombs for targets too small to warrant the use of an atomic bomb. Increases in accuracy could cause a substantial reduction in this figure of 300 atomic bombs, to as few as 100-150 bombs for very accurate attacks.

WESTERN AUSTRALIA.

CIVIL DEFENCE COUNCIL

AIR RAID PRECAUTIONS

HANDBOOK No. 8.

The Duties of Air Raid Wardens

(REVISED EDITION 1941)

Issued by Authority of the Civil Defence Council.

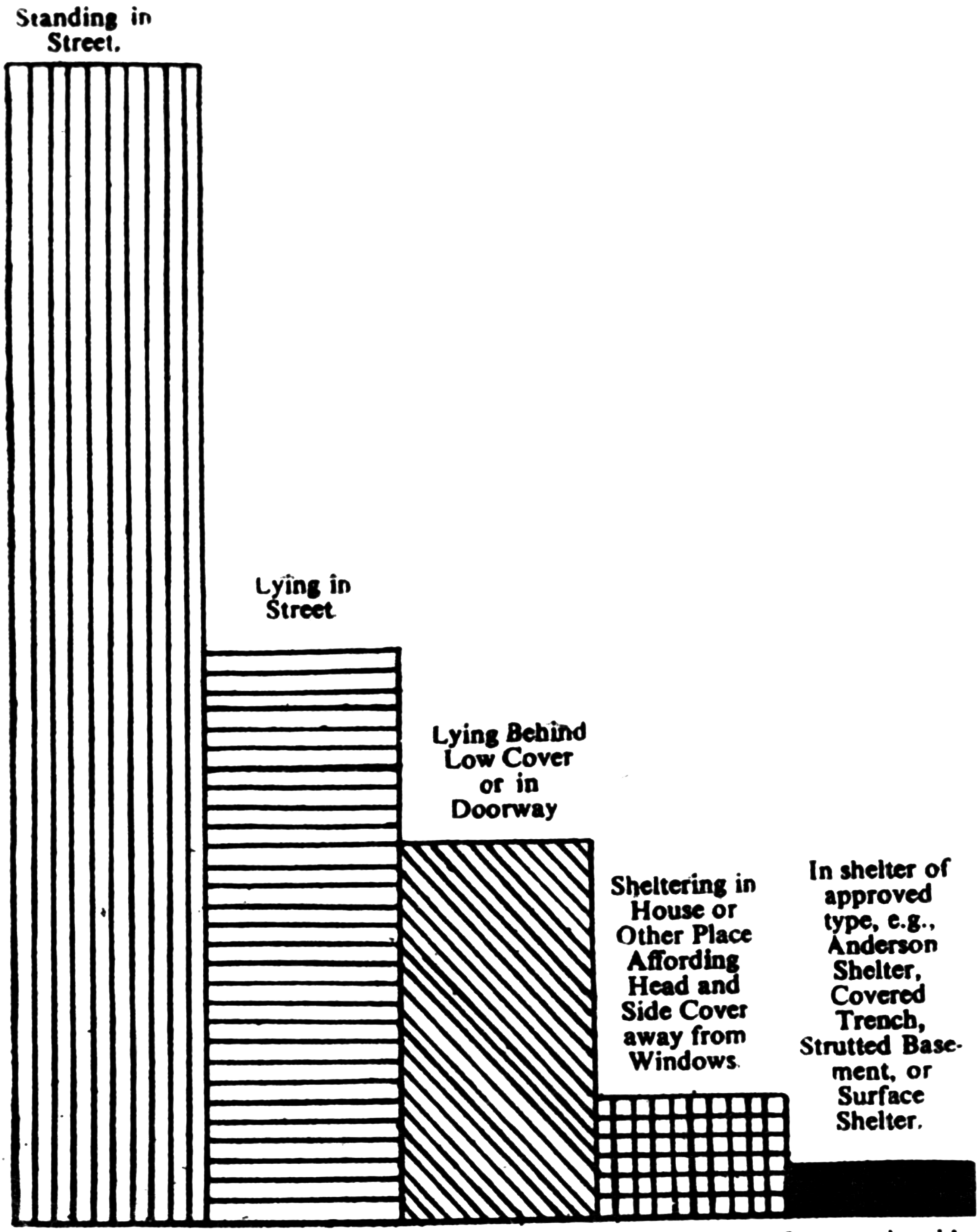
PERTH:

BY AUTHORITY: FRED. WM. SIMPSON, GOVERNMENT PRINTER.

1941.

1 088/41.

The following diagram is appended to illustrate the relative degree of protection afforded by the open street, by door-ways, by the interior of ordinary dwellings, and by simple shelters of approved design:—



This diagram is based on a large number of reports of the results of recent air raids and is an approximate indication of the difference in the degree of risk resulting from taking cover in various ways

HOME OFFICE

THE PROTECTION OF YOUR HOME AGAINST AIR RAIDS

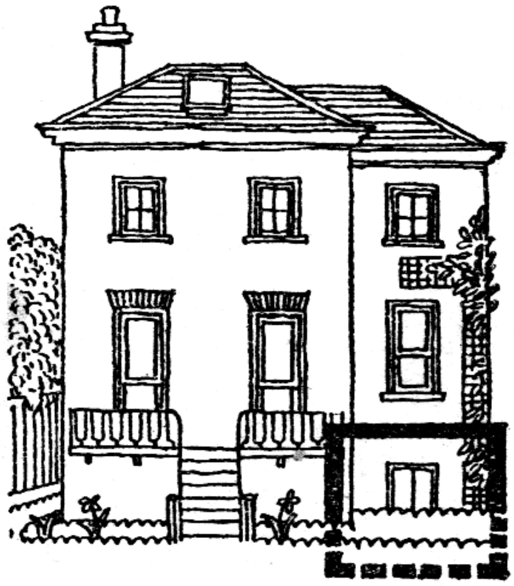
READ THIS BOOK THROUGH

THEN

KEEP IT CAREFULLY

HOW TO CHOOSE A REFUGE-ROOM

Almost any room will serve as a refuge-room if it is soundly constructed, and if it is easy to reach and to get out of. Its windows should be as few and small as possible, preferably facing a building or blank wall, or a narrow street. If a ground floor room facing a wide street or a stretch of level open ground is chosen, the windows should if possible be specially protected (see pages 30 and 31). The stronger the walls, floor, and ceiling are, the better. Brick partition walls are better than lath and plaster, a concrete ceiling is better than a wooden one. An internal passage will form a very good refuge-room if it can be closed at both ends.

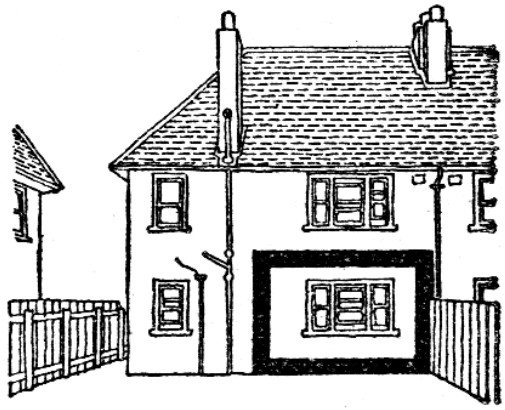


A cellar or basement is the best position for a refuge-room if it can be made reasonably gas-proof

The best floor for a refuge-room

A cellar or basement is the best place for a refuge-room if it can be made reasonably gas-proof and if there is no likelihood of its becoming flooded by a neighbouring river that may burst its banks, or by a burst water-main. If you have any doubt about the risk of flooding ask for advice from your local Council Offices.

Alternatively, any room on any floor below the top floor may be used. Top floors and attics should be avoided as they usually do not give sufficient protection overhead from small incendiary bombs. These small bombs would probably penetrate the roof but be stopped by the top floor, though they might burn through to the floor below if not quickly dealt with.

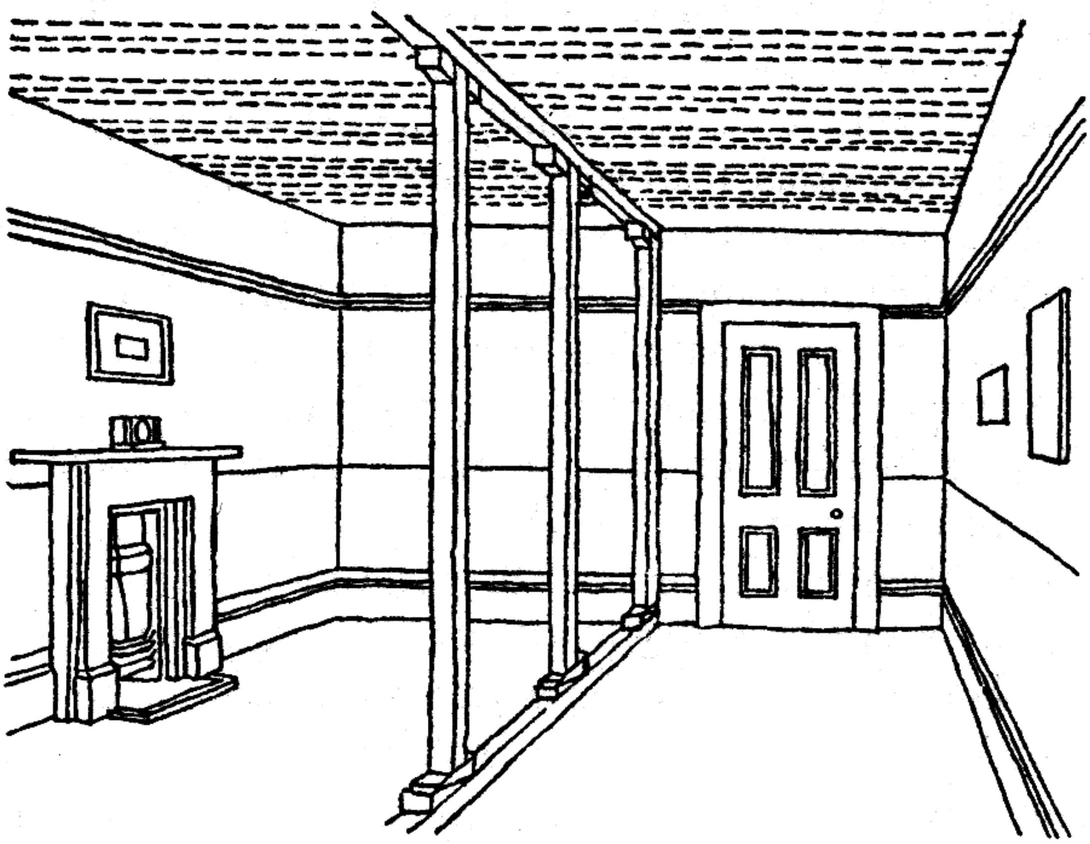


In a house with only two floors and without a cellar, choose a room on the ground floor so that you have protection overhead

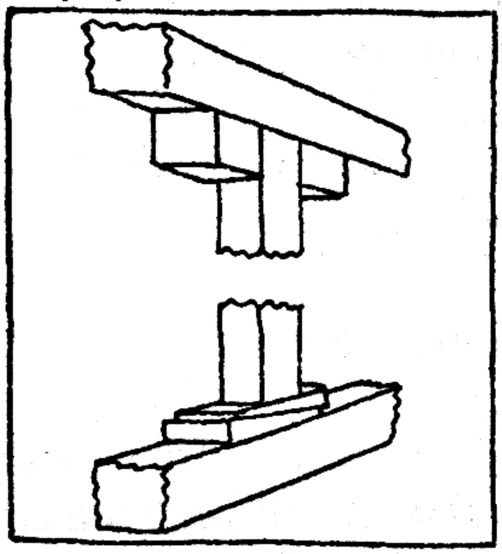
Strengthening the room

If your refuge-room is on the ground floor or in the basement, you can support the ceiling with wooden props as an additional protection. The illustration shows a way of doing this, but it would be best to take a builder's advice before setting to work. Stout posts or scaffold poles are placed upright, resting on a thick plank on the floor and supporting a stout piece of timber against the ceiling, at right angles to the ceiling joists, i.e. in the same direction as the floor boards above.

How to support a ceiling



The illustration below shows the detail of how to fix the props

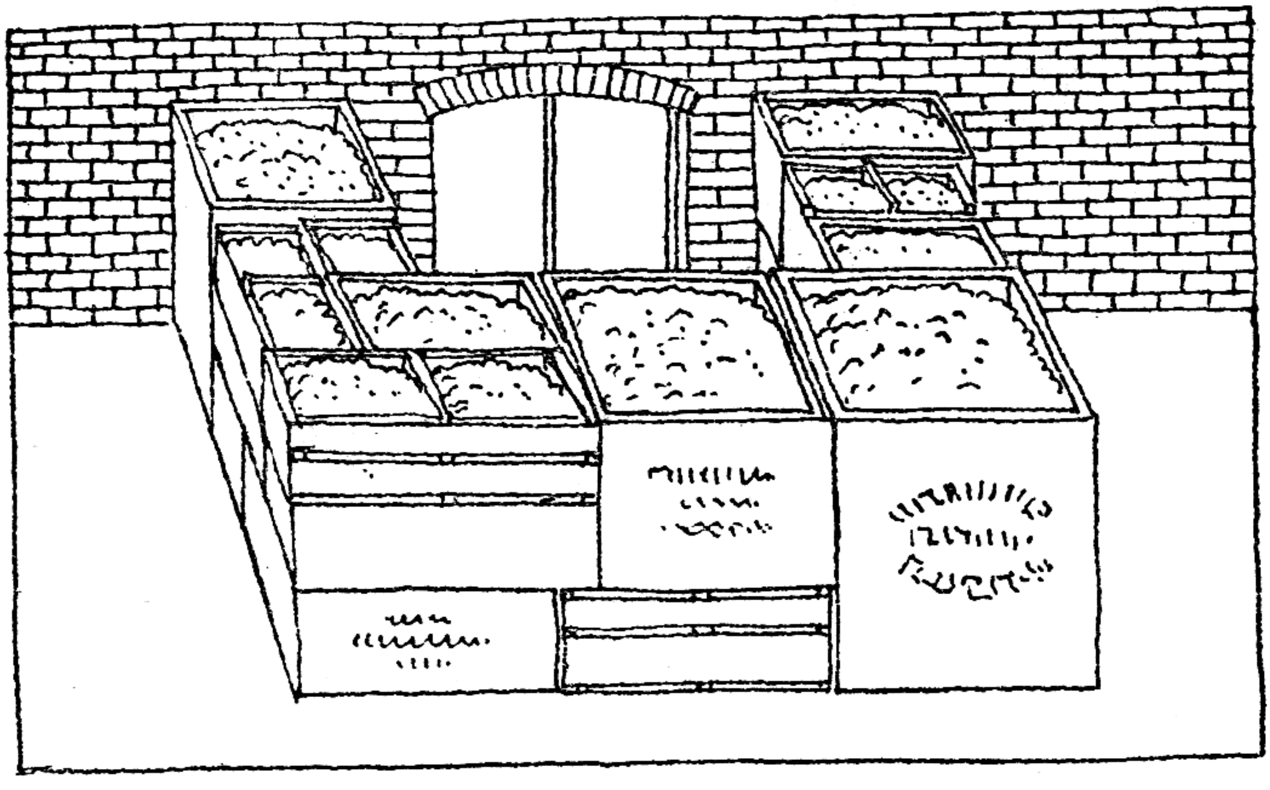


The smaller illustration shows how the posts are held in position at the top by two blocks of wood on the ceiling beam. The posts are forced tight by two wedges at the foot, driven in opposite ways. Do not drive these wedges too violently, otherwise you may lift the ceiling and damage it. If the floor of your refuge-room is solid, such as you might find in a basement, you will not need a plank across the whole floor, but only a piece of wood a foot or so long under each prop.

EXTRA PRECAUTIONS AGAINST EXPLOSIVE BOMBS

TRENCHES. Instead of having a refuge-room in your house, you can, if you have a garden, build a dug-out or a trench. A trench provides excellent protection against the effects of a bursting bomb, and is simple to construct. Full instructions will be given in another book which you will be able to buy. Your air raid wardens will also be able to advise.

SANDBAGS. Sandbags outside are the best protection if your walls are not thick enough to resist splinters. Do not rely on a wall keeping out splinters unless it is more than a foot thick. Sandbags are also the best protection for window openings. If you can completely close the window opening with a wall of sandbags you will prevent the glass being broken by the blast of an explosion, as well as keeping out splinters. But the window must still be sealed inside against gas.



A basement window protected by boxes of earth

Any bags or sacks, including paper sacks such as are used for cement, will do for sandbags. But if they are large, don't fill

ALL persons involved in accidents suffer from shock, whether or not they suffer physical injury. Shock is a disturbance of the nervous system. It varies in its severity. The signs of shock are faintness, paleness, weak pulse, and weak breathing.

TREATMENT OF SHOCK

1 Place the patient flat on his back on a bed or a rug or on cushions. If you think a bone may be broken do not move the patient more than can be helped.

2 Loosen the clothing at the neck, chest and waist to make the breathing freer.

3 Cover the patient warmly with rugs and blankets. In cases of shock the body loses heat. A hot-water bottle is helpful, but take care that it does not lie in contact with the skin.

4 Give hot drinks. If you cannot make hot drinks, give cold water *in sips*. But only if the patient is conscious and able to swallow.

5 Soothe the patient by speaking reassuring words in a calm voice and in a confident way.

TREATMENT OF WOUNDS

The first thing to do is to stop the bleeding and to keep the wound clean. This can be done by covering it with a clean dressing bound on tightly. Do not touch a wound with your fingers because of the risk of poisoning from dirt. Treat the patient for shock in addition to attending to the wound, because the loss of blood, if the wound is serious, and the pain do in themselves cause shock.

WOUNDS IN THE HEAD AND BODY

1 Cover the wound with a clean folded handkerchief or a double layer of dry lint.

2 Apply another handkerchief or a layer of cotton wool as a pad to distribute the pressure over the wound.

3 Tie the dressing in position with a bandage, a strip of linen, or a necktie. This can be done quite firmly, unless there is any foreign body, especially glass, in the wound, or unless the bone is broken. In this case the dressing should be tied on lightly.

4 Treat the patient for shock.

CIVIL DEFENCE

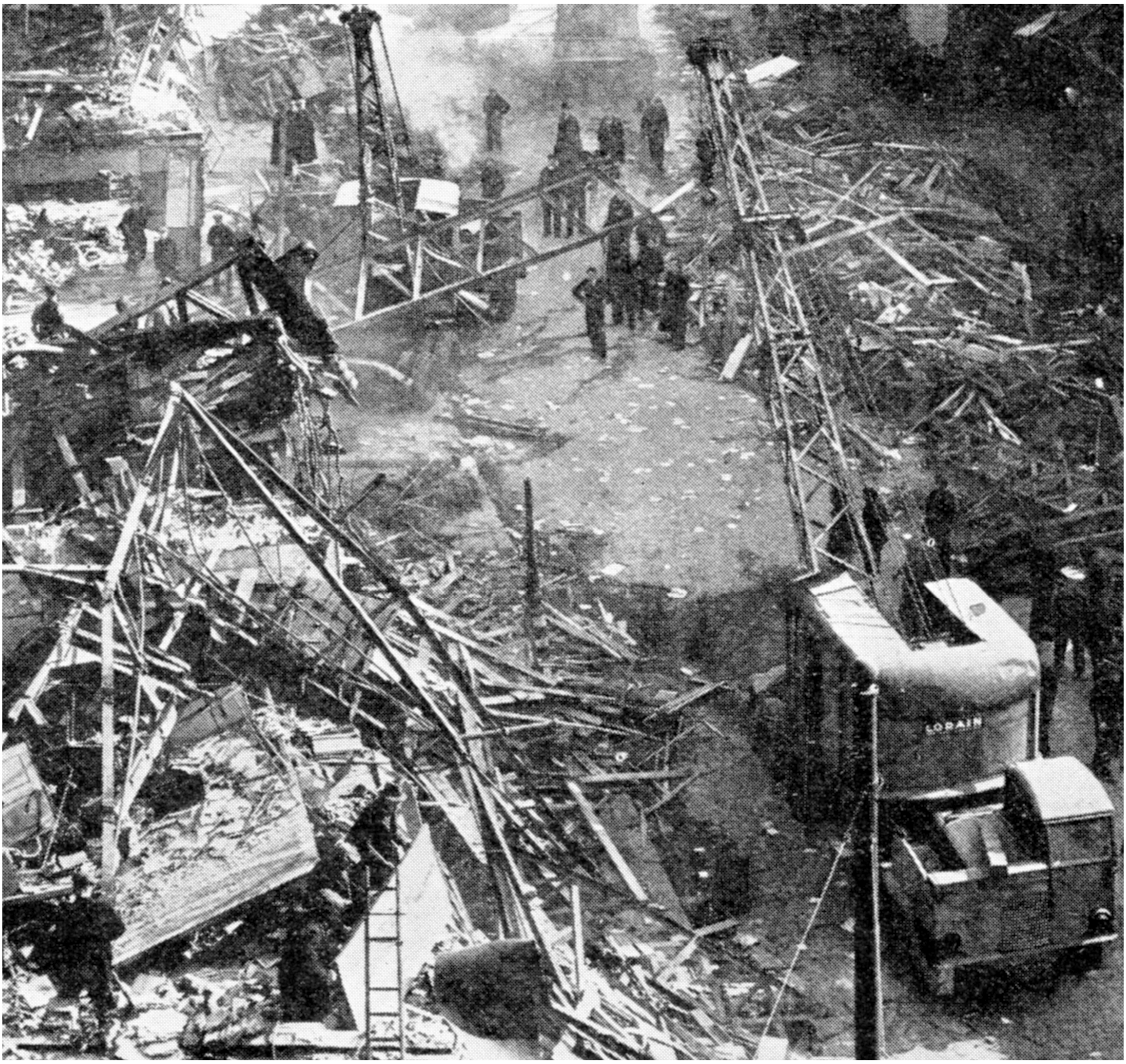
RESCUE MANUAL

LONDON
HER MAJESTY'S STATIONERY OFFICE
1952

CHAPTER XI. USE OF HEAVY MECHANICAL PLANT IN RESCUE, DEMOLITION AND CLEARANCE OPERATIONS

In the last war it was found that at major incidents the use of heavy mechanical plant was frequently necessary in support of rescue operations. Such equipment was used to help in the quick removal of debris; to lift heavy blocks of brickwork or masonry; to take the weight of collapsed floors and girders so that voids could be explored and casualties extricated; to haul off twisted steelwork and other debris and to break up sections of reinforced concrete.

In future all these tasks may be required and heavy clearance may have to be effected to enable rescue and other Civil Defence vehicles



8 March 1945 Fig. 20 **1 ton of TNT equivalent**

Using heavy mechanical plant at the Smithfield Market V.2 incident.

to approach within measurable distance of their tasks. The problem of debris will in fact be a major factor in Civil Defence operations.

Heavy mechanical plant may be required for the following purposes :

(*a*) To assist in the removal of persons injured or trapped. At this stage mainly heavy plant is needed, particularly mobile cranes with sufficient length of boom or jib to reach for long distances over the wreckage of buildings.

(*b*) To force a passage for Civil Defence vehicles and fire appliances to enable them to reach areas where major rescue and other problems exist and require urgent operational action.

(*c*) To take certain safety measures—e.g., to pull down unsafe structures.

(*d*) To clear streets and pavements to help restore communications and to afford access for the repair of damaged mains and pipes beneath the streets.

(*e*) For the final clearance of debris and the tidying of sites. This is a long term and not an operational requirement.

Urgent Rescue Operations

During rescue operations in London in the last war the machines used with great success included heavy 3½-5 ton mobile cranes, mounted on road wheels, with a 30-40 ft. jib ; medium heavy 2-3½ ton mobile cranes, mounted on road wheels, with a 26 ft. jib ; heavy crawler tractor bulldozers ; medium crawler tractor bulldozers ; mechanical shovels and compressors, three stage, mounted on road wheels.

In the case of a large or multiple incident where access was obstructed by considerable quantities of scattered debris, a bulldozer or tractor was first employed in order to clear one or more approaches by which other equipment and personnel could reach the scene of operations.

Next, all debris of manhandling size was loaded into one-yard skips and discharged by the crane into lorries, giving increased manœuvring space to the Services operating on the site.

Heavy mobile cranes were then brought up to the incident where, used under the skilled direction of the rescue party Leader, they were invaluable for removing girders and large blocks of masonry which obstructed access to casualties or persons trapped. The necessary chains and wire ropes for these operations formed part of the standard equipment of the heavy and medium-heavy mobile cranes.

The work was, of course, carried out in close co-operation with the Rescue Parties who also used various forms of light mechanical equipment, such as jacks and ratchet lifting tackle for work in confined spaces.

Compressors sometimes proved valuable for breaking up large masonry such as fallen walls, into sections of a size and weight within the handling and lifting capacity of the cranes. This method was only used when it was known that there were no casualties under the masonry.

HOME OFFICE
SCOTTISH HOME DEPARTMENT

Civil Defence Instructors Notes

RESCUE SECTION

LONDON
HER MAJESTY'S STATIONERY OFFICE
1957

Elementary Rescue Training

EMERGENCY METHODS OF MOVING CASUALTIES

Notes for Instructor

1 Reference : Rescue Pamphlet, Chapter IV.

2 Instructor requires an assistant to act as casualty and an additional man to help demonstrate the methods mentioned in paragraph 7. Selected frames from Film Strips CD6 and 7 will be found useful.

Object of Lesson

3 To explain and teach various types of hand carriage for EMERGENCY use in moving casualties where need for speed precludes use of casualty handling equipment, as preliminary to actual practice.

Emergency

4 When casualty is in danger of receiving further injuries, by fire, coal gas, flooding or from dangerous structures, such as leaning walls, etc., it is necessary to remove cause of danger from casualty or casualty from the danger. If vital to remove casualty to safety, he must be removed regardless of his injuries. Only when casualty is in imminent danger of death by remaining where he is does removal take priority over stoppage of bleeding.

Choice of Method

5 Various types of hand carriage include five suitable for one rescuer and five for more than one rescuer. Choice of method depends upon :

(*a*) Nature of casualty's injuries : Slight or serious, conscious or unconscious.
(*b*) Position in which casualty is found : Ample space, narrow void, limited headroom.
(*c*) Number of rescuers.

Methods Suitable for one Rescuer

6 Explain and teach following methods, vide Rescue Pamphlet :

(*a*) Pick-a-back.
(*b*) Human crutch.
(*c*) Fireman's lift.
(*d*) Rescue crawl. (Previously known as the Fireman's crawl.)
(*e*) Removal downstairs.

Methods Suitable for more than one Rescuer

7 Explain and teach the following methods, vide Rescue Pamphlet :

(*a*) Two man human crutch.
(*b*) The fore and aft method.
(*c*) Two handed seat.
(*d*) Three handed seat.
(*e*) Four handed seat.

Concluding Summary

8 The object has been to explain and teach various types of hand carriage for emergency use in moving casualties where need for speed precludes use of casualty handling equipment, as preliminary to actual practice. **ONLY WHEN CASUALTY IN IMMINENT DANGER OF DEATH BY REMAINING WHERE HE IS DOES REMOVAL TAKE PRIORITY OVER STOPPAGE OF BLEEDING.**

HOME OFFICE

SCOTTISH HOME DEPARTMENT

CIVIL DEFENCE HANDBOOK No. 7

Rescue

This Handbook is a revised edition of,
and replaces, the
Civil Defence Rescue Manual

LONDON

HER MAJESTY'S STATIONERY OFFICE

1960

CHAPTER 6

Types of Damage from Modern Air Attack

General Characteristics

6.1 When a nuclear weapon explodes an immense amount of energy is released almost instantaneously and the contents are transformed into a rapidly expanding white hot ball of gas at a temperature as high as that on the sun. From this "fireball" a pulse of intense light and heat is radiated in all directions. The materials in the fireball are also a source of radioactivity in various forms. As the fireball expands and cools, a powerful blast wave develops. As it cools still further, it shoots upwards to a height of many thousands of feet, billowing out at the top to give the appearance of a huge mushroom or cauliflower on its stalk.

6.2 The three forms of energy released in the explosion, namely, light and heat, radioactivity, and blast, all produce effects in different ways and in different proportions according to the position of the explosion in relation to the surface underneath. This chapter, however, deals primarily with the damage caused to buildings by the blast effect.

6.3 With nuclear weapons (as opposed to high explosive weapons), blast pressure rather than "impulse" tends to be the criterion of damage. If the effective blast pressure exceeds the static strength of the structure, failure must be expected. If it is less, no failure can occur however long the duration of the blast. In fact, nuclear bomb blast is more like a strong wind than the sudden blow of high explosive blast, and many of the failures observed at Hiroshima and Nagasaki and in subsequent tests resemble closely the kind of damage that might be done to buildings by a hurricane.

6.4 The scarcity of suction damage from the nominal bombs in Japan was due to the high blast pressures produced and to the fact that these were three or four times as great as the blast suction. With all such large explosions, if a building does not fail from blast pressure it is unlikely to fail under the lower stresses in the suction phase.

Effect of blast on structures

6.5 The type of damage which long duration blast (from nuclear weapons) causes to structures can possibly best be appreciated by considering the forces to which a simple building is subjected during the passage of a horizontal blast wave. When the blast "front" strikes the front wall it is reflected back, and the pressure in the wave front builds up to more than double the original pressure. However, this build-up only lasts for a very short time and is mainly important for large flat surfaces such as walls of big buildings.

Fig. 39 (a). Using a door as a stretcher

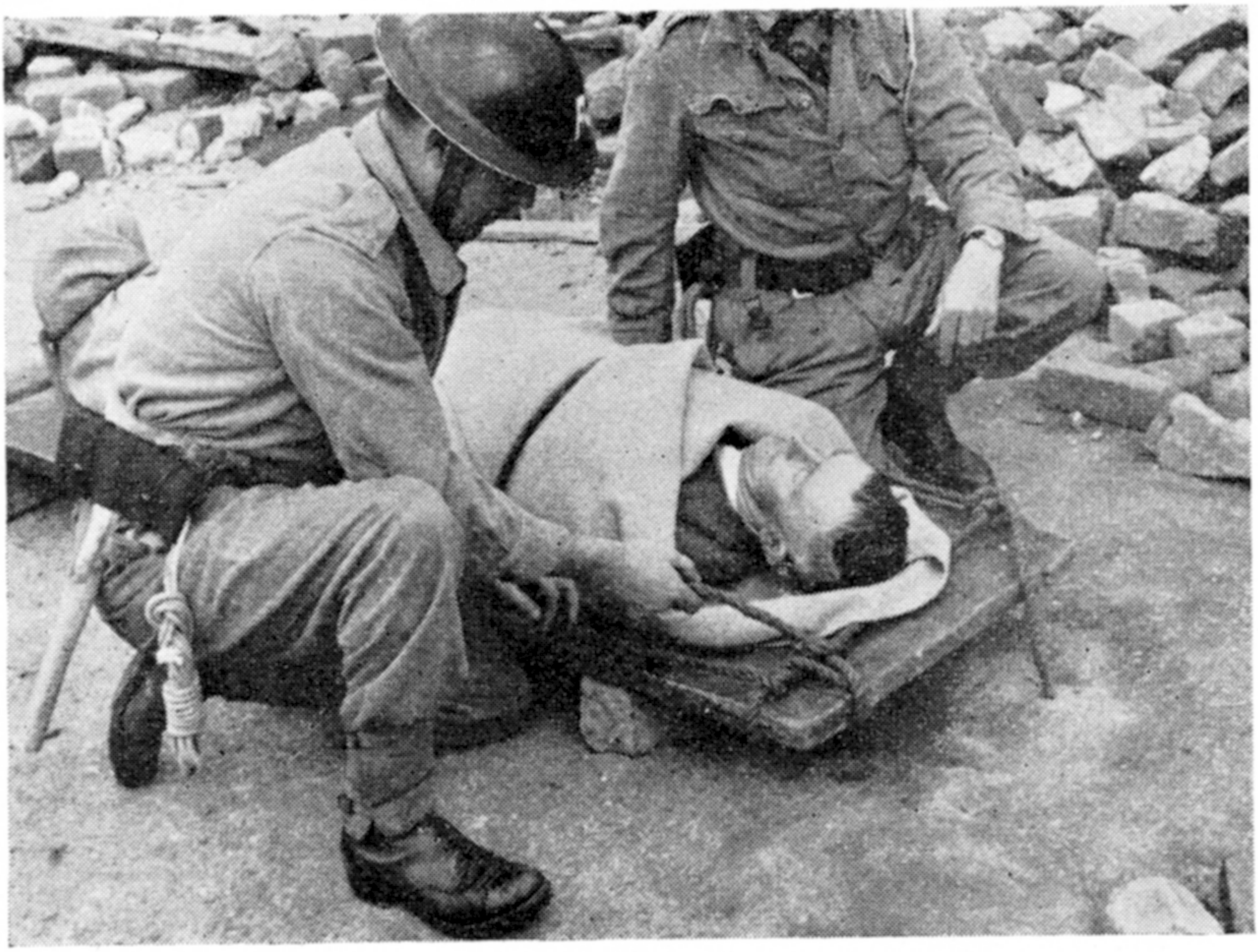


Fig. 39 (b). Using a door as a stretcher

CHAPTER 15

Principles of Levering and Jacking

15.1 The principles of levering and jacking are, in a variety of differing ways, brought into most aspects of rescue work. The purpose of lifting appliances is to gain power so as to lift a large load with a small force suitably applied.

Levers

15.2 The simplest appliance for gaining power is the lever, of which an improvised version made of laminated timber or an ordinary crowbar are most frequently used by rescue workers. There are two principal ways in which a lever can be used, as illustrated in the diagrams. In each case the advantage gained depends on the distance of (A), the centre of the load, and (C) the points where the push or force is applied from (B), the heel or fulcrum.

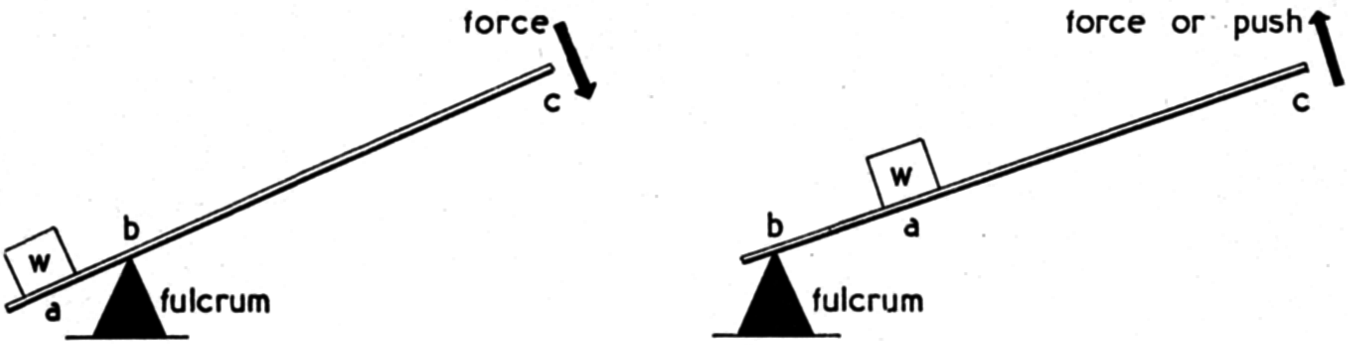


Fig. 68. Lever (downward force) Lever (upward force)

15.3 The relation between the load and the amount of force required to lift it is in the same ratio as the length BC is to AB, where AB and BC are the distances of the weight and the force respectively from the fulcrum. A man using a 10-foot lever and bearing down at C with half his weight, say, 6 stone or 84 lb., against a fulcrum 1 foot from the other end of the lever, can lift a weight of $84 \times 9 = 756$ lb. because the length from fulcrum to hand is nine times the length from pivot to weight. If B is only 6 inches away from the weight the ratio is increased to 19 times its own weight.

Fulcrum blocks

15.4 A fulcrum block should be of wood (hardwood if possible), never of brick or other crushable material. It must be resting on a firm base, which should be as large as possible so as to distribute the weight to be lifted. The fulcrum must be placed as near to the weight as is possible under the circumstances, and it should never be placed at any point where there is a possibility of a casualty being buried immediately below.

Fig. 140. Surface casualties caused by the effects of an explosion

Fig. 141. Interior of slightly damaged building showing lightly trapped casualty

32.21 Slightly damaged houses should be marked when they have been searched and any casualties attended to (and removed if necessary).

Marking buildings after search

32.22 The objects of markings are to:

(i) Save time and labour by indicating that the buildings have been searched for casualties and cleared.

(ii) Indicate the service responsible for the search, e.g. wardens.

(iii) Show if the building contains some particular danger.

Only slightly damaged buildings which have been thoroughly searched can safely be so marked and the following standard marking must be used. A capital letter 'S' chalked near the entrance will denote that the building has been searched and cleared of casualties. This will be underlined and underneath will be chalked the initial letter of the service responsible for the search, thus:

$\frac{S}{W}$ searched by Warden Section

$\frac{S}{F}$ searched by Fire Service

$\frac{S}{P}$ searched by Police

$\frac{S}{LR}$ searched by those trained in Light Rescue

$\frac{S}{R}$ searched by Rescue Section

Where searchers find dangerous conditions, e.g. leaning walls, damaged staircases, holes in floors, escaping coal gas etc. they should chalk the letter 'D' after the standard marking. Thus the symbol—

$\frac{S}{W}$ D

means that the building has been searched by wardens and that dangers have been found, but could not be rectified at that time. This will warn others who may be sent at a later date (e.g. members of the Rescue Section, public utility company employees etc.) to rectify such dangers.

32.23 Buildings in which dangers exist should be marked in a prominent position on all sides where entry is likely to be made. In addition to the mark, a piece of board or some improvised barricade with the word "DANGER" chalked or written on it, or even string tied across an opening, will assist in warning anyone who has occasion to enter the building.

32.24 If debris is present in sufficient quantity to hide casualties, only mark those parts of the building which have been thoroughly searched.

Calling and listening technique

32.27 When it is known that persons are still missing, and the rescuers are confronted with a major collapse of premises, the casualties may be trapped within the voids formed by the collapsing building. A "calling and listening" period should be introduced; this has in the past saved many lives and is carried out in the following manner:

The leader places such men as may be available at suitable vantage points around the area in which the persons may be trapped. He then demands complete silence and each man as directed by the leader calls "RESCUE PARTY HERE . . . CAN YOU HEAR ME?" All others listen intently for any reply. If none is heard it is a good plan to tap on a wall, or on any gas or water pipe, beam etc., running *into* the debris, all of which are good conductors of sound, and again listen for an answer. On hearing a reply, each listener points to the place from which he thinks the sound came, thus "pinpointing" the position. Once contact has been established with a trapped person it should be maintained, because:

(a) It keeps up his morale and helps him to withstand whatever pain and discomfort he may be suffering, and may even help to keep him alive.

(b) It helps the rescuers to decide on the best place at which to start and to work in the right direction, often a difficult matter, particularly in the dark.

(c) The casualty, if conscious, may be able to give warning of any movement in the debris likely to cause him further injury.

32.28 No attempt should be made to move debris until a "calling and listening" period has been introduced with a view to pin-pointing the position of the casualties. Since the detection and location of sounds is a most vital clue to rescue section personnel, every sound, even if obviously made by animals, should receive investigation.

32.29 Conversation with a trapped person should always be of a reassuring nature, making light of the extrication work and encouraging him to talk about his own work, his friends or anything that will relieve his mind, rather than about his position or injuries.

Stages 1-3

32.30 The work involved in the foregoing stages may frequently be done by those trained in light rescue or elementary rescue, working in teams, although in some cases they may require the assistance of fully trained rescue men to advise or even to *complete* a particular task, e.g. rescue from upper floors of badly damaged buildings, or of any seriously injured casualties etc.

32.31 One or all of the stages may be operated simultaneously according to personnel available and other circumstances.

Use of dogs

32.32 Specially trained dogs were used with conspicuous success on a number of occasions during the later stages of the last war, and proved their

value as an adjunct to rescue reconnaissance, especially in the "third stage of rescue". A searching dog, trained to locate human scent, can lead to a very considerable saving of time and labour in the definite location and extrication of casualties. The dogs when brought to the scene of rescue operations can often quickly provide an indication of the position of a trapped or buried person which otherwise might take some time to determine by normal rescue reconnaissance methods. Highly trained dogs and handlers may well play an important part in rescue operations in any future war and their possible use has not been overlooked.

Fig. 143. A specially trained dog at work during rescue operations

Stage 4—Further exploration and selected debris removal

32.33 If casualties are located, their recovery will entail removing debris from selected places, according to:

(i) The location of the casualty.

(ii) Information regarding the lay-out of the building.

(iii) A careful study of the way in which the building has collapsed. See Chapter 19 "Rescue by Debris Clearance" for detail of methods adopted.

Stage 5—General Debris Clearance

32.34 Where it is still impossible to account for all missing persons it may be necessary to strip the site methodically. See Chapter 19 "Rescue by Debris Clearance" for details.

In 12 months, 1940-1, the Blitz stray dog Rip (discovered by civil defence rescuers in Poplar, East London after an air raid) sniffed out 100 trapped casualties in London rubble.

Irma. Margaret Griffin used Irma and Psyche to find 233 trapped persons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ARP
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Amended Reprint
June, 1940

AIR RAID PRECAUTIONS
HANDBOOK No. 9

(*1st edition*)

INCENDIARY BOMBS AND FIRE PRECAUTIONS

Issued by the
Ministry of Home Security

LONDON
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE

INTRODUCTION.

The object of incendiary bombs is to cause fires, and it may be asked, " Why cannot these be dealt with by the Fire Brigades? Why should members of the public be expected to undertake fire fighting? " The answers to these questions can be given in a few words.

The number of fires which might be started by an air raid, or a series of air raids, must be a matter of conjecture, but obviously might be very large (see Chapter I). Briefly it may be stated that one large bomber can carry between 1,000 and 2,000 small incendiary bombs, which if scattered over built-up areas, and not dealt with within two or three minutes after falling, might start so many fires that no fire brigade could be expected to deal with them all.

Moreover, the water mains might be damaged or drained dry for fire fighting elsewhere, with the result that there might not be enough water nearby for a fire engine to use; or, again, roads might be damaged by high explosive bombs and so prevent a fire engine from reaching the site of the fire.

Steps have been taken to augment fire brigades for the purpose of dealing with the emergency problem, but it will readily be appreciated that sufficient appliances might not be available to deal with every fire that might be caused by incendiary bombs; and, as each fire left unattended in a building is a potential " burn out " of that and possibly neighbouring buildings, it is obviously of vital importance that as many of the public as possible should be in a position to deal with fires on their own property, before they have a chance of spreading so as to require the assistance of the fire brigade. This is particularly important in the case of factories, works, hospitals, schools, and other large institutions (see Chapter VI).

It must be emphasized also that dealing with incendiary bomb attack is mainly a question of ordinary fire fighting and ordinary fire precautions, and that much of the information and advice given in the following pages is, therefore, equally applicable to peace-time conditions.

CHAPTER I.

The Light Magnesium Bomb.

Several types and sizes of incendiary bomb have been tried at one time or another by different countries, but the pattern which is most likely to be used, on account of its effectiveness, is a bomb commonly referred to abroad as an electron bomb, probably weighing no more than 1 kilo.

Description of the kilo magnesium bomb.

This type of bomb (Figs. 1 and 2) consists of a thick walled tube 9 in. long and 2 in. in diameter, made of an alloy of magnesium with a small proportion of aluminium. On one end of this tube there is a tail 5 in. long to steady the bomb in flight. The tube is filled with a priming composition of the thermite type. The bomb is fitted with an igniter which may be situated either in the nose or in the rear end of the tube.

The bomb weighs about 2 lb. 2 oz. and, with the exception of a few ounces in the tail and igniter, there is no dead weight, the whole being incendiary material. This is an important point to remember when the efficiency of this bomb is compared with that of other types.

How the bomb functions.

The bomb functions on impact, a needle in the igniter being driven into a small percussion cap which ignites the priming composition. The bomb does not explode.

It should be noted that, although this bomb is often called a thermite bomb, or a thermite electron bomb, the main incendiary agent is not the thermite composition but the magnesium tube, which is not in itself readily inflammable. The priming composition burns for 40/50 seconds at a temperature of about 2,500° C., and its great heat serves to melt and ignite the magnesium tube. The molten magnesium burns for 10 to 15 minutes at a temperature of about 1,300° C.; it may remain active for as long as 20 minutes, and will set fire to anything inflammable within a few feet.

During the first 50 seconds or so, while the priming composition is still burning, the bomb looks very violent; jets of flame are emitted from vent holes, and pieces of

Fig. 1—Typical Kilo Magnesium Incendiary Bomb.

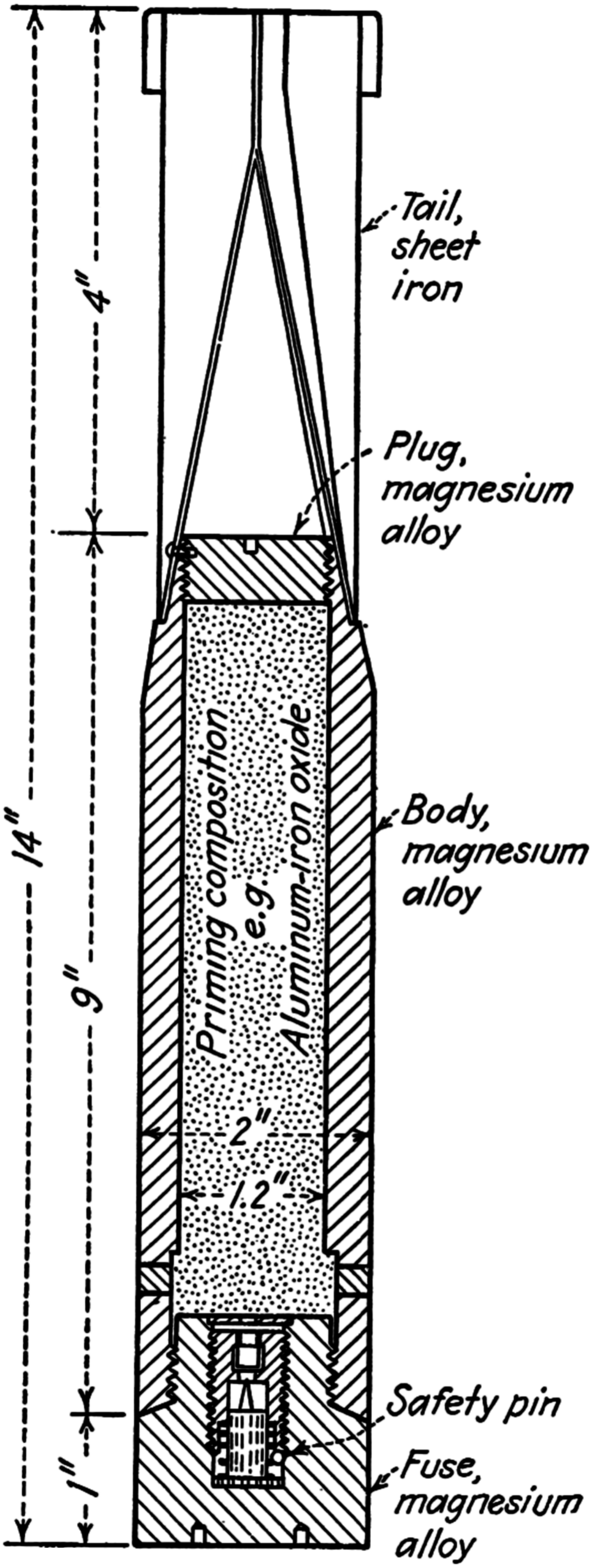

Fig. 2—Typical Kilo Magnesium Incendiary Bomb. Sectional Drawing.

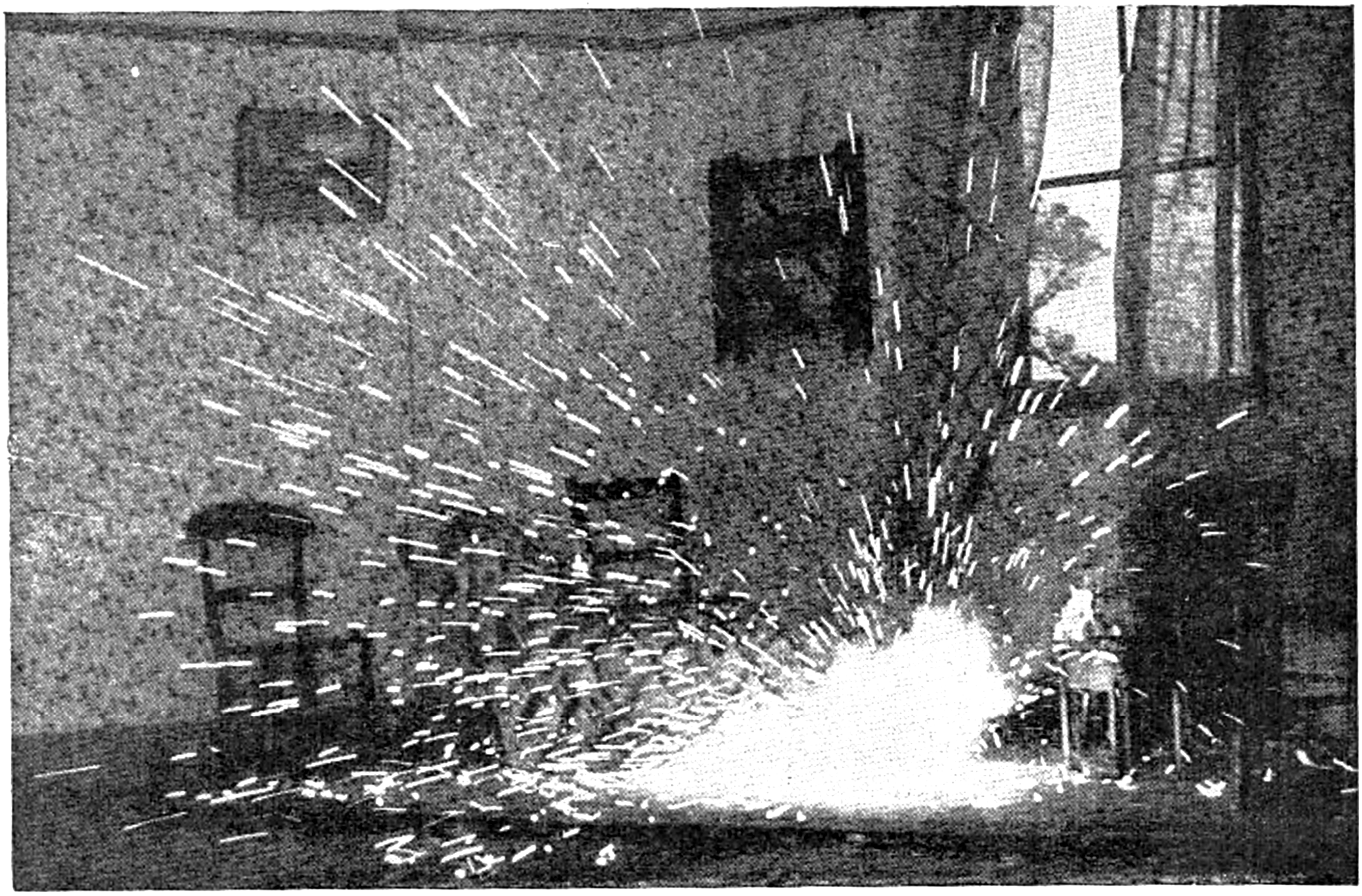

FIG. 4—KILO MAGNESIUM INCENDIARY BOMB 15 SECONDS AFTER IGNITION.

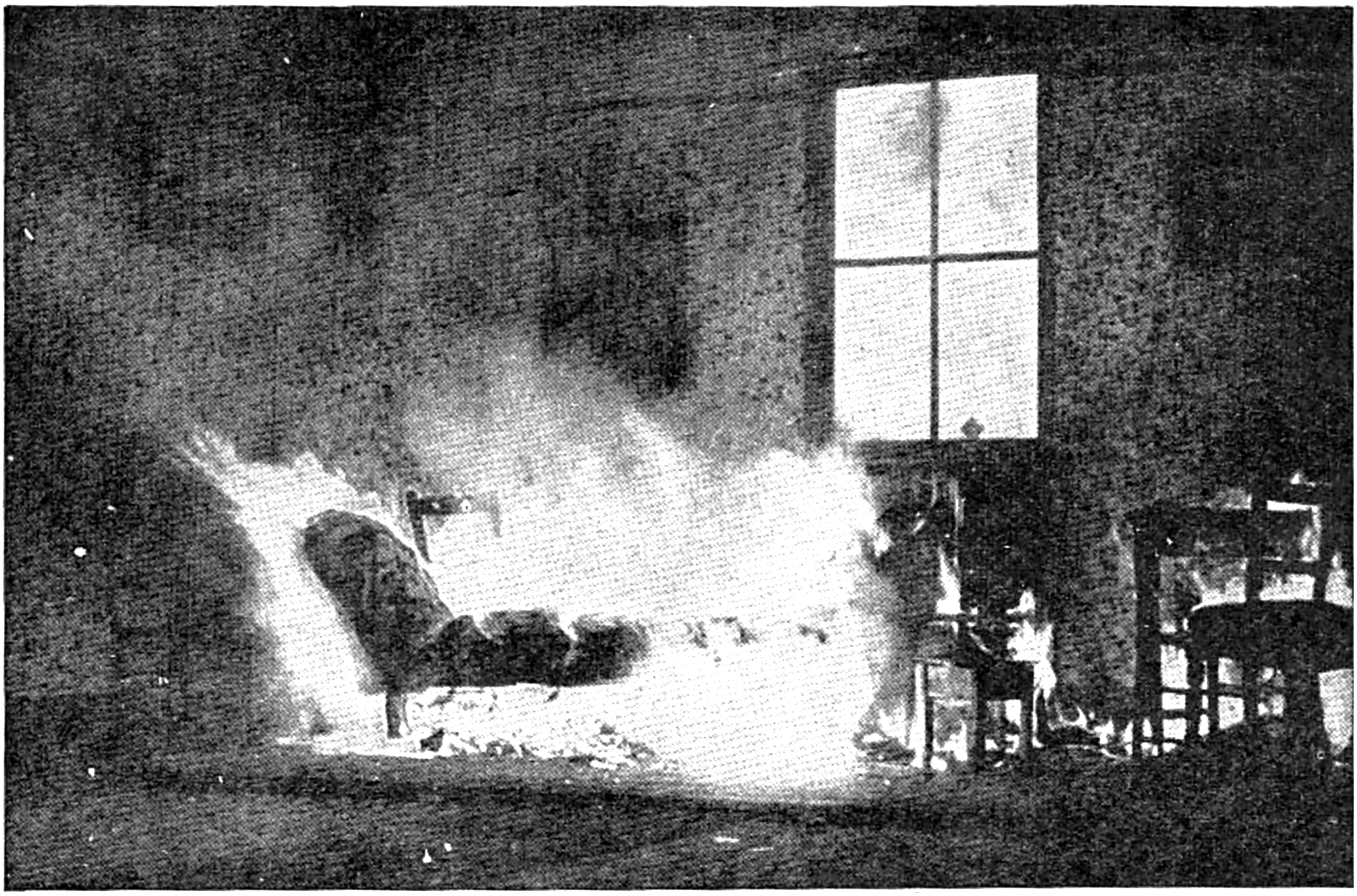

FIG. 5—FIRE CAUSED BY KILO MAGNESIUM INCENDIARY BOMB 45 SECONDS AFTER IGNITION.

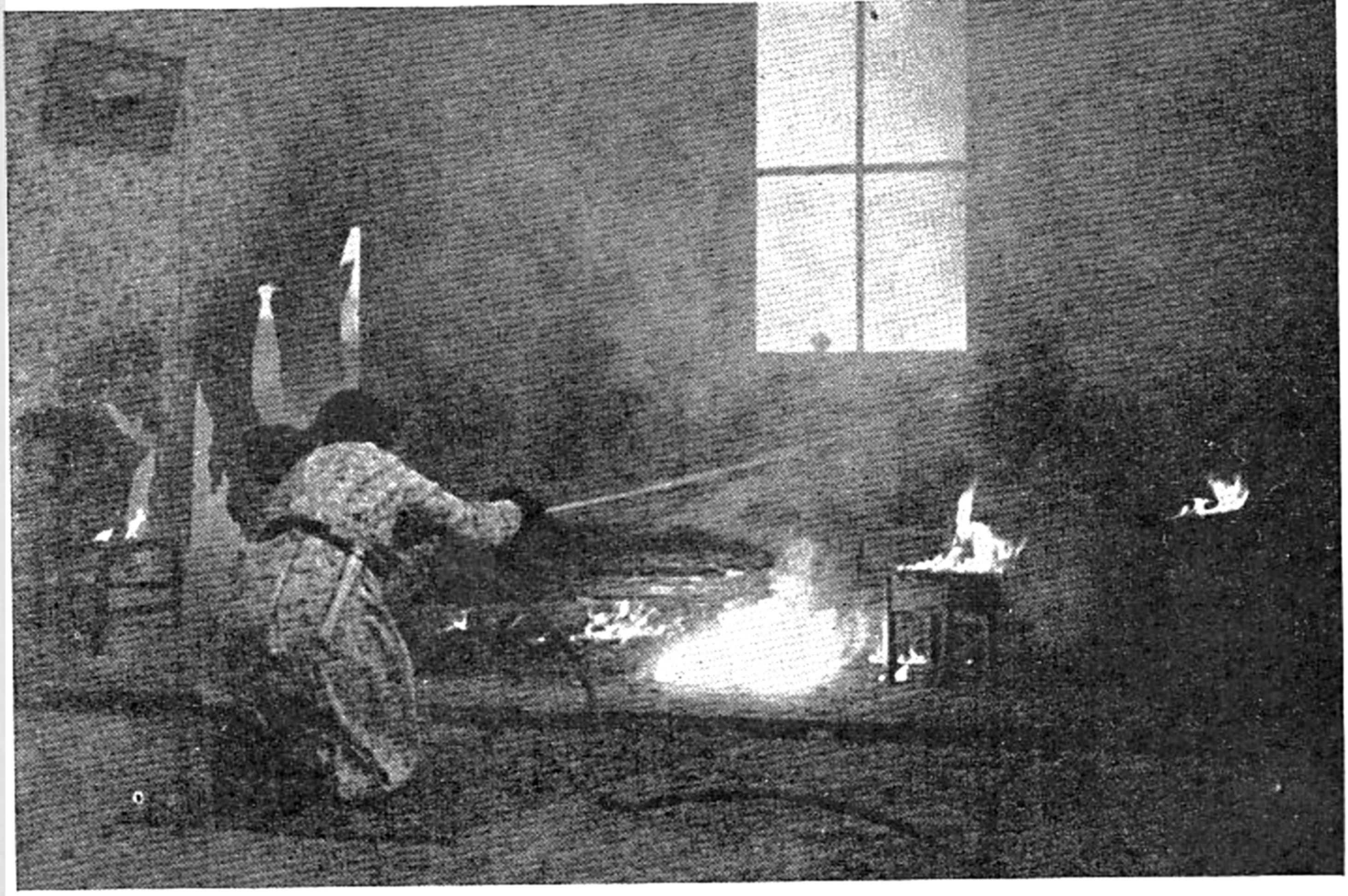

FIG. 6—FIRE CONTROLLED BY WATER USING JET FROM STIRRUP HAND-PUMP.

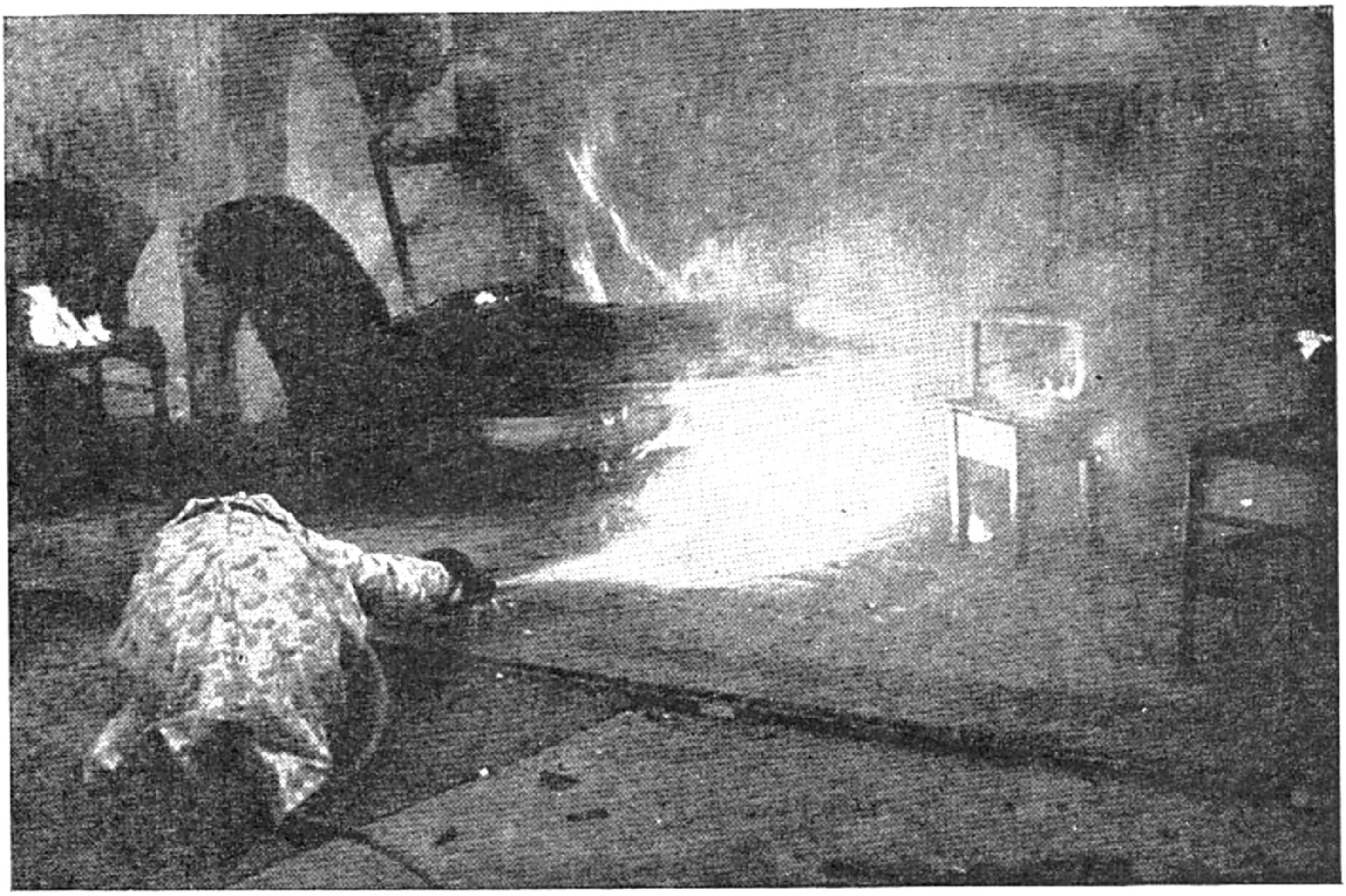

FIG. 7—WATER APPLIED TO BURNING BOMB USING SPRAY FROM STIRRUP HAND-PUMP.

Clothing on fire.

Never allow a person whose clothes are on fire to remain standing for a moment. Fatalities nearly always arise from shock of burning about the face and head. If the person starts to run, trip him up at once. Roll him on the floor or in a coat or blanket if you have one handy. If your own clothes catch fire, clap your hand over your mouth, and lie down and roll.

Escaping through a window.

If you have to escape from a room by the window without the aid of a rope, or even of sheets joined together, do not jump. Sit on the window-sill with your legs outside, turn over, and slide out till you have a finger grip on the edge of the window-sill and then let go. The drop will be reduced by the length of your reach and body (Figs. 15, 16, and 17).

To lower a person from a window.

Place the rope under the shod instep and three points of friction will be obtained, which will make the lowering of the heaviest person relatively easy (Fig. 18). For practice purposes, a dummy or a weight should be used.

Note.—Escape from a window should only be attempted as a last resource.

Extinguishing a fire.

Quite a small pumping appliance, such as the stirrup hand-pump, should extinguish a fire in any one room if used with promptitude, pluck, and intelligence. But you will do little good unless you can attack the heart of the fire from fairly close range, say, at most 25 ft.

When a fire is inside a room keep the door closed till appliances are in position and ready to operate, and never open up a floor or cut away any woodwork to get at a fire till you are ready to attack it.

Do not overlook the possibility of a fire travelling under a floor, behind matchboarding, or up a shaft. A fire extinguished in one place has often been known to start again elsewhere.

There is more than one side to every fire. Attack may be difficult on one side, and relatively easy on another.

Note.—A hat worn well forward will give some protection to the forehead against heat, and allow closer approach to the fire.

Fig. 15

Fig. 16

Fig. 17

Escaping Through a Window.

Feasibility

In the typical household, some materials will generally be available for covering windows against thermal radiation. One half roll of aluminum foil would cover about 25 ft^2 and would provide very effective covering for 1 to 2 windows (those most likely to face the blast). Sufficient quantities of either light colored paint, Bon Ami, or whiting would be available in most households to cover windows. Aluminum screens attenuate from 30 - 50% of the thermal radiation and hence screens should be closed or installed.

The amount of water per square foot required to dissipate 25 cal/cm^2 of thermal radiation can quickly be calculated from the heat of vaporization of water (580 cal/gm). Allowing 90% losses due to absorption or spillage, one gallon of water is sufficient to wet 10 ft^2 of material so that it can withstand 25 cal/cm^2 of direct thermal radiation (i.e., the radiation is normal to the material surface at all points). Since the average daily water consumption per service (Reference 3) is about 700 gallons, it is apparent that the wetting of interior flammables (piled up curtains, furniture, etc.) is feasible in most cases when used in conjunction with the other measures.

3. Statistical Abstracts of the United States. Washington: U. S. Government Printing Office, 1962.

~~CONFIDENTIAL~~

DEPARTMENT OF THE ARMY TECHNICAL MANUAL — TM 23-200

DEPARTMENT OF THE NAVY — OPNAV INSTRUCTION 03400.1B

DEPARTMENT OF THE AIR FORCE — AFL 136-1

MARINE CORPS PUBLICATIONS — NAVMC 1104 REV

CAPABILITIES OF ATOMIC WEAPONS (U)

Prepared by
Armed Forces Special Weapons Project

DEPARTMENTS OF THE ARMY, THE NAVY AND THE AIR FORCE

REVISED EDITION NOVEMBER 1957

~~CONFIDENTIAL~~

c. Indirect Blast Injury.

(1) *General.* Indirect blast casualties result from burial by debris from collapsed structures with attendant production of fractures and crushing injuries, from missiles placed in motion by the blast wave, or from fire or asphyxiation where individuals are prevented from escaping the wreckage.

(2) *Personnel in structures.* A major cause of personnel casualties in cities is structural collapse and damage. The number of casualties in a given situation may be reasonably estimated if the structural damage is known. Table 6–1 shows estimates of casualty production in two types of buildings for several damage levels. Data from Section VII may be used to predict the ranges at which specified structural damage occurs. Demolition of a brick house is expected to result in approximately 25 percent mortality, with 20 percent serious injury and 10 percent light injury. On the order of 60 percent of the survivors must be extricated by rescue squads. Without rescue they may become fire or asphyxiation casualties, or in some cases be subjected to lethal doses of residual radiation. Reinforced concrete structures, though much more resistant to blast forces, produce almost 100 percent mortality on collapse. The figures of table 6–1 for brick homes are based on data from British World War II experience. It may be assumed that these predictions are reasonably reliable for those cases where the population is in a general state of expectancy of being subjected to bombing and that most personnel have selected the safest places in the buildings as a result of specific air raid warnings. For cases of no prewarning or preparation, the number of casualties is expected to be considerably higher. To make a good estimate of casualty production in structures other than those listed in table 6–1, it is necessary to consider the type of structural damage that occurs and the characteristics of the resultant missiles. Glass breakage extends to considerably greater ranges than almost any other structural damage, and may be expected to produce large numbers of casualties at ranges where personnel are relatively safe from other effects, particularly for an unwarned population.

Table 6–1. Estimated Casualty Production in Structures for Various Degrees of Structural Damage

	Killed outright	Serious injury (hospitalization)	Light injury (No hospitalization)
1–2 story brick homes (high explosive data):	*Percent*	*Percent*	*Percent*
Severe damage	25	20	10
Moderate damage	<5	10	5
Light damage	------	<5	<5
Reinforced-concrete buildings (Japanese data, nuclear):			
Severe damage	100	------	------
Moderate damage	10	15	20
Light damage	<5	<5	15

Note. These percentages do not include the casualties which may result from fires, asphyxiation, and other causes from failure to extricate trapped personnel. The numbers represent the estimated percentage of casualties expected at the maximum range where the specified structural damage occurs.

Personnel in a prone position are less likely to be struck by flying missiles than those who remain standing.

Table 6–2. Critical Radiant Exposures for Burns Under Clothing

(Expressed in cal/cm² incident on outer surface of cloth)

Clothing	Burn	1 KT	100 KT	10 MT
Summer Uniform	1°	8	11	14
(2 layers)	2°	20	25	35
Winter Uniform	1°	60	80	100
(4 layers)	2°	70	90	120

cue

FOR SURVIVAL

OPERATION CUE

A. E. C. NEVADA TEST SITE

MAY 3, 1955

A REPORT BY THE

FEDERAL CIVIL DEFENSE ADMINISTRATION

EFFECTS OF NUCLEAR WEAPONS

BY HAROLD L. GOODWIN,
Director, Atomic Test Operations, FCDA

A great deal of information has been released over the past several years on the effects of atomic explosions, yet many of these effects are still poorly understood by the general public. For that reason, the principal effects of a nuclear explosion are reviewed, with a brief discussion of factors of particular importance to civil defense.

This entire section is based on informaton available in published sources. There is a widespread but erroneous view that most information on the effects of nuclear explosions is classified, and hence is not available to the general public. Information that exists only in classified form generally is information which deals with refinements of weapons effects. A considerable amount of gross information on any major effect is available in a number of publications.

The best reference in this field is still the basic handbook, *The Effects of Atomic Weapons.* Despite the fact that this useful work was first published in 1950, queries daily to the Federal Civil Defense Administration indicate that it has not been widely studied or understood. A thoughtful reading will be of value to any person with civil defense responsibility. A revision, now in process, may be issued in the next few months.

The time of travel of the shock wave is not generally understood by many persons. The concept of "duck and cover," which would still be of great value in case of attack without warning, is based on the comparatively large time interval between the burst and arrival of the shock wave at a given point.

It takes several seconds for the shock wave of a nominal bomb to reach a point 2 miles from the burst. A person who moved promptly at the first light of the detonation would have time to get under or behind a convenient piece of furniture, or other protection. At greater distances there would be even more time.

This time lapse between the detonation and arrival of the shock wave was graphically demonstrated to persons watching from the observer areas in the Test Site. The detonation takes place, a phenomenon without sound from the viewpoint of the observer. So much time elapses between the detonation and arrival of the shock wave that observers sometimes forget that the shock wave is on its way and the loud bang of its arrival finds them unprepared. Persons are frequently startled and have even been pushed off balance by the shock wave. The pause between a lightning flash and the thunder is comparable.

The question may be asked, how will one know when a burst has gone off if the sound does not arrive for some time? The answer is that the light from the explosion is its own warning.

BIOMEDICAL EFFECTS OF THERMAL RADIATION

BY DR. HERMAN ELWYN PEARSE, *Professor of Surgery at the University of Rochester. Consultant to several Government departments, notably the Atomic Energy Commission's Division of Biology and Medicine. Consultant to the Armed Forces Special Weapons Project*

After the Bikini test, I was asked to go to Japan as a consultant for the National Research Council to survey the casualties in Nagasaki and Hiroshima. Being a surgeon, I was greatly impressed with the magnitude of the medical problem from burns and wounds very largely caused by flying missiles. They constituted roughly 85 percent of the casualties in Japan.
140

In Japan it was an August day, the people were lightly clothed, and they were out in the open.
141

Then we observed the healing of the wounds, and we found again that the wounds healed in the same manner as those that we had produced in the laboratory. There was some difference in these lesions from the ordinary burns of civil life, but I would predict, from what I learned from experiments, that the difference is on the good side. The burns look worse; they are often charred, but they may not penetrate as deeply, and the char acts as a dressing, nature's own dressing. The scab solidifies, and the healing process goes on under that scab, after which the scab is sequestrated, and the healed surface is revealed beneath.
142

I didn't care what happened to the fabrics; I wanted to know what happened to the man under the fabric. So we conceived this idea, that the important factor in studying clothing was what happened under the clothing; how it shielded the animal with cloth of different composition, weight, texture, weave, and color. We have made a great many studies both in the laboratory and in the field on this problem of the protective effect of clothing....

For example, if you have 2 layers, an undershirt and a shirt, you will get much less protection than if you have 4 layers; and if you get up to 6 layers, you have such great protection from thermal effects that you will be killed by some other thing. Under 6 layers we only got about 50 percent first degree burns at 107 calories.
143

If we can just increase the protection a little bit, we may prevent thousands and thousands of burns.

... For example, to produce a 50-percent level of second-degree burns on bare skin required 4 calories. When we put 2 layers of cloth in contact, it only took 6 calories. But separate that cloth by 5 millimeters, about a fifth of an inch, and it increases the protective effect 5 times. The energy required to produce the same 50-percent probability of a second-degree burn is raised up to 30 calories. So if you wear loose clothing, you are better off than if your wear tight clothing.
144

UR-261

Health and Biology

THE UNIVERSITY OF ROCHESTER
Atomic Energy Project
P. O. Box 287, Station 3
Rochester 20, New York

Contract W-7401-eng-49

* * *

STUDIES ON FLASH BURNS: THE PROTECTION AFFORDED BY 2, 4 AND 6 LAYER FABRIC COMBINATIONS

by:

George Mixter and Herman E. Pearse

Division: Special Programs

Section: Flash Burn

Division Head: H. A. Blair

Section Head: H. D. Kingsley

Submitted by: Henry A. Blair,
Director

Date of Report: 6/4/53

STUDIES ON FLASH BURNS:

THE PROTECTION AFFORDED BY 2, 4 AND 6 LAYER FABRIC COMBINATIONS

by

George Mixter, Jr., M. D. and Herman E. Pearse, M. D.

ABSTRACT

Fabric interposed between a carbon arc source and the skin of Chester White pigs increased the amount of thermal energy required to cause 2+ burns. For the 2, 4 and 6 layers of fabric studied this increase was 3.6, 38 and over 104 cal/cm^2 respectively when the inner layer of fabric was in contact with the skin. Separation of the inner layer from the skin by 5 mm increased the protective effect of the 2 layer combination from 7.4 to 29 cal/cm^2, provided the outer layer was treated for fire retardation. If the outer layer was not so treated, sustained flaming occurred which in itself added to the thermal burn.

INTRODUCTION

In the past, work in this laboratory has been directed toward a study of flash burns in unshielded skin. It is well known from the atomic bombing in Japan that this type of burn was modified by clothing. A laboratory analysis of the protective effect of fabrics against flash burns was begun (5) by shielding the skin with a few representative fabrics and their combinations.

1. 2 Layers
   a. light green oxford
      knitted cotton underwear
   b. light green oxford (HPM)
      knitted cotton underwear
2. 4 Layers
   olive green sateen
   thin cotton oxford
   wool-nylon shirting
   knitted cotton underwear
3. 6 Layers
   olive green sateen
   thin cotton oxford
   mohair frieze
   rayon lining
   wool-nylon shirting
   knitted wool underwear

5. Morton, J. H., Kingsley, H. D., and Pearse, H. E., "Studies on Flash Burns: The Protective Effects of Certain Fabrics", Surgery, Gynecology and Obstetrics, 94, 497-501 (April 1952).

Clothing protects back, 1 mile from ground zero Hiroshima, aged 17. Photo taken October 1945. Unclothed arms burned facing burst.

Above and below: clothing fails to ignite on mannequins located at 7000 feet from ground zero, 29 kt Teapot-Apple 2, 5 May 1955.

Addendum No. 1

for

DNA 1240H-2, Part 2

HANDBOOK OF UNDERWATER NUCLEAR EXPLOSIONS

21 January 1974

M. J. Dudash
DASIAC
General Electric Company–TEMPO
816 State Street
Santa Barbara, CA 93102

CHAPTER	TITLE	PAGE
	VOLUME 2 – PART 2	
18	SURFACE SHIP PERSONNEL CASUALTIES: EFFECTS OF UNDERWATER SHOCK ON PERSONNEL	18-1

19 August 1973 CHAPTER 18

18.7 THERMAL AND NUCLEAR RADIATION EFFECTS ON SURFACE SHIP PERSONNEL

18.7.1 Casualty and Risk Criteria

Table 18-2

CDC NUCLEAR AND THERMAL RADIATION CRITERIA

New Thermal Radiation Criteria

Risk Criteria for Burns Under Summer Uniforms to Warned, Exposed Personnel

	% Incidence	Mechanism	10KT cal/cm^2	100KT cal/cm^2	1000KT cal/cm^2
Negligible	2.5	1° burn	3.1	4.2	5.8
Moderate	5	1° burn	3.7	5.0	6.8
Emergency	5	2° burn	6.3	8.8	12

	Casualties due to 2nd Degree Burns			
Time to Ineffectiveness	% Incidence	10KT cal/cm^2	100KT cal/cm^2	1000KT cal/cm^2
24. hr	50	38	53	73

Personnel Risk and Casualty Criteria for Nuclear Weapons Effects
ACN 4260, U. S. Army Combat Developments Command Institute of Nuclear Studies, August 1971

RADIOLOGICAL DEFENSE

Vol. II

The Principles of Military Defense against Atomic Weapons

Armed Forces Special Weapons Project

November 1951

FOREWORD

While the atomic bomb is admittedly a weapon of great power, it is not to be regarded as an absolute weapon—that is to say, it is not a weapon against which there is no defense. Throughout history, the introduction of every new weapon has been followed by the development of defensive measures which have lessened its effectiveness. However, the development of suitable defensive measures against atomic weapons requires an understanding of the characteristics and effects of these weapons under various circumstances. Unfortunately, many misleading and exaggerated reports of the consequences of such weapons have received wide publicity, and these have made more difficult the task of those responsible for the planning of atomic defense.

The original drafts of the material for this volume were prepared at the Naval Radiological Defense Laboratory, San Francisco, partly from contributions of its staff and partly from material supplied by other representatives of the Armed Services who collaborated in this work. It is regretted that it is not feasible to list the names of the many individuals, both uniformed and civilian, who have assisted in the assembly and review of the contents of this book. Their efforts are sincerely appreciated. It is also desired to acknowledge the valuable assistance rendered by the Atomic Energy Commission in making available Dr. Samuel Glasstone, who acted as Executive Editor in the final rewriting and integration of the manuscript.

HERBERT B. LOPER
Brigadier General, USA
Chief, Armed Forces Special Weapons Project

1.05. The three planes, which appeared over the city so soon after an "all clear" had been given, were not taken seriously. It was thought that they were observation planes, and even if they had been bombers, their bomb load was evidently not considered sufficient to merit a further disruption of the city's daily routine. From the standpoint of defense against the atomic bomb, the important lesson is that no enemy plane, whether it comes singly or in a group, can be disregarded. Had the inhabitants of Hiroshima remained in their shelters, the number of casualties would have been greatly decreased.

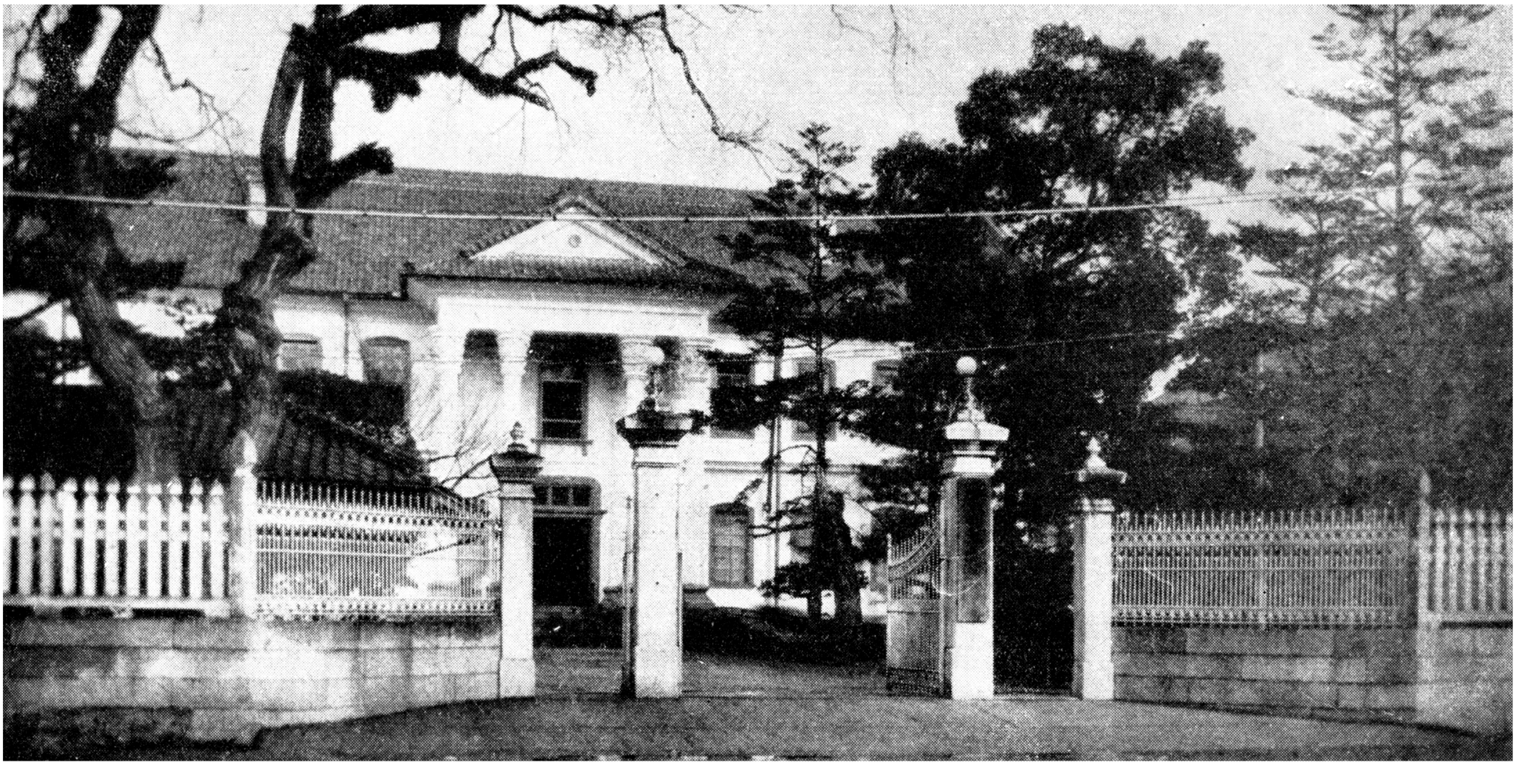

Figure 1.02a. The Hiroshima Prefecture (approximately 1,000 yards from ground zero) before the atomic explosion.

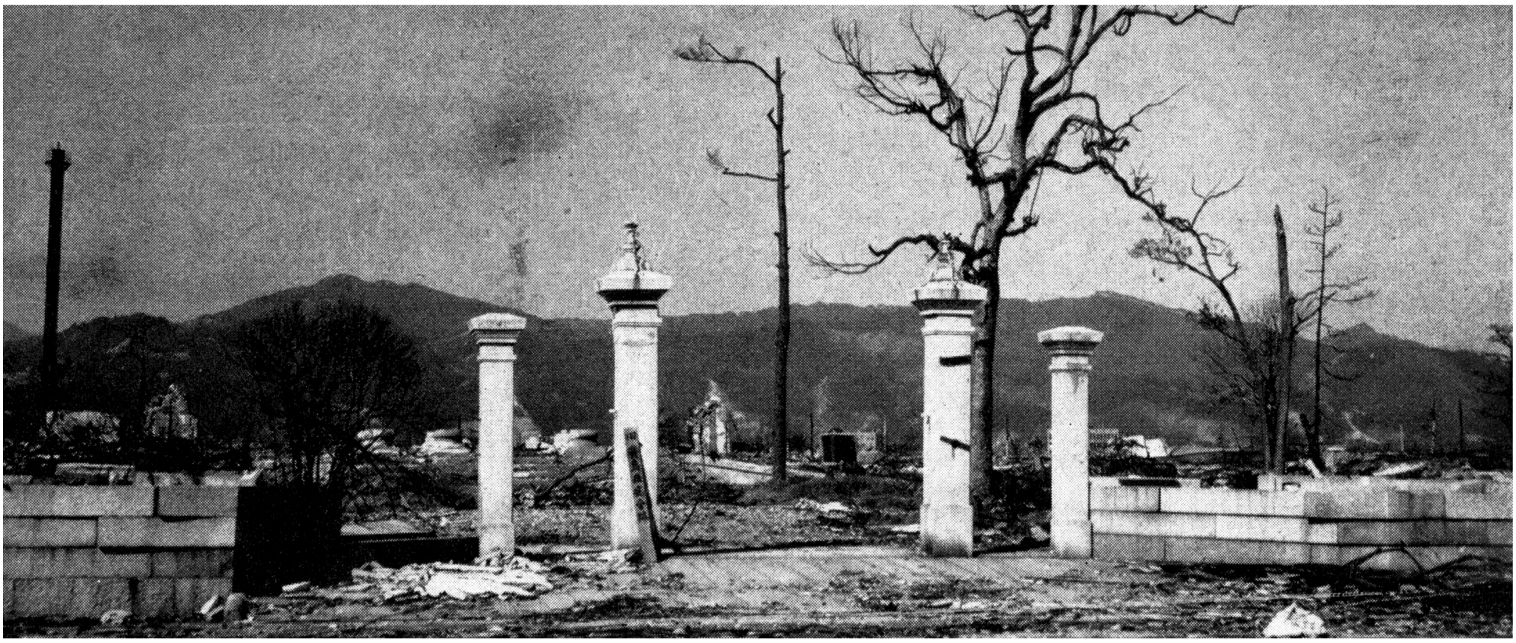

Figure 1.02b. The Hiroshima Prefecture after the atomic explosion.

1.09. Since a large number of the inhabitants as well as considerable residential areas of the city survived the explosion, rescue efforts at Nagasaki were soon organized. The water supply was partially restored by the second day after the dropping of the bomb, and some electric power was available at the end of the same day. On the following day a few streetcars and railway trains were running again.

Comparison of Atomic and Conventional Bombs

	Hiroshima Atomic Bomb	Nagasaki Atomic Bomb	Tokyo 1,667 tons Incendiary and TNT	Average of 93 Attacks 1,129 tons Incendiary and TNT per attack
Square miles destroyed	4.7	1.8	15.8	1.8

Primary and Secondary Fires

6.31. Fires accompanying an atomic explosion may be distinguished as primary or secondary, according to their origin. Primary fires are those caused directly by the thermal radiation igniting paper, thin cloth, rags, wood, dry vegetation, etc. Secondary fires are due to other causes, for which the blast is mainly responsible, such as upset stoves and furnaces, broken gas and other fuel lines, electrical short circuits, and so on. The evidence from Hiroshima and Nagasaki indicated that the great majority of fires were secondary in nature.

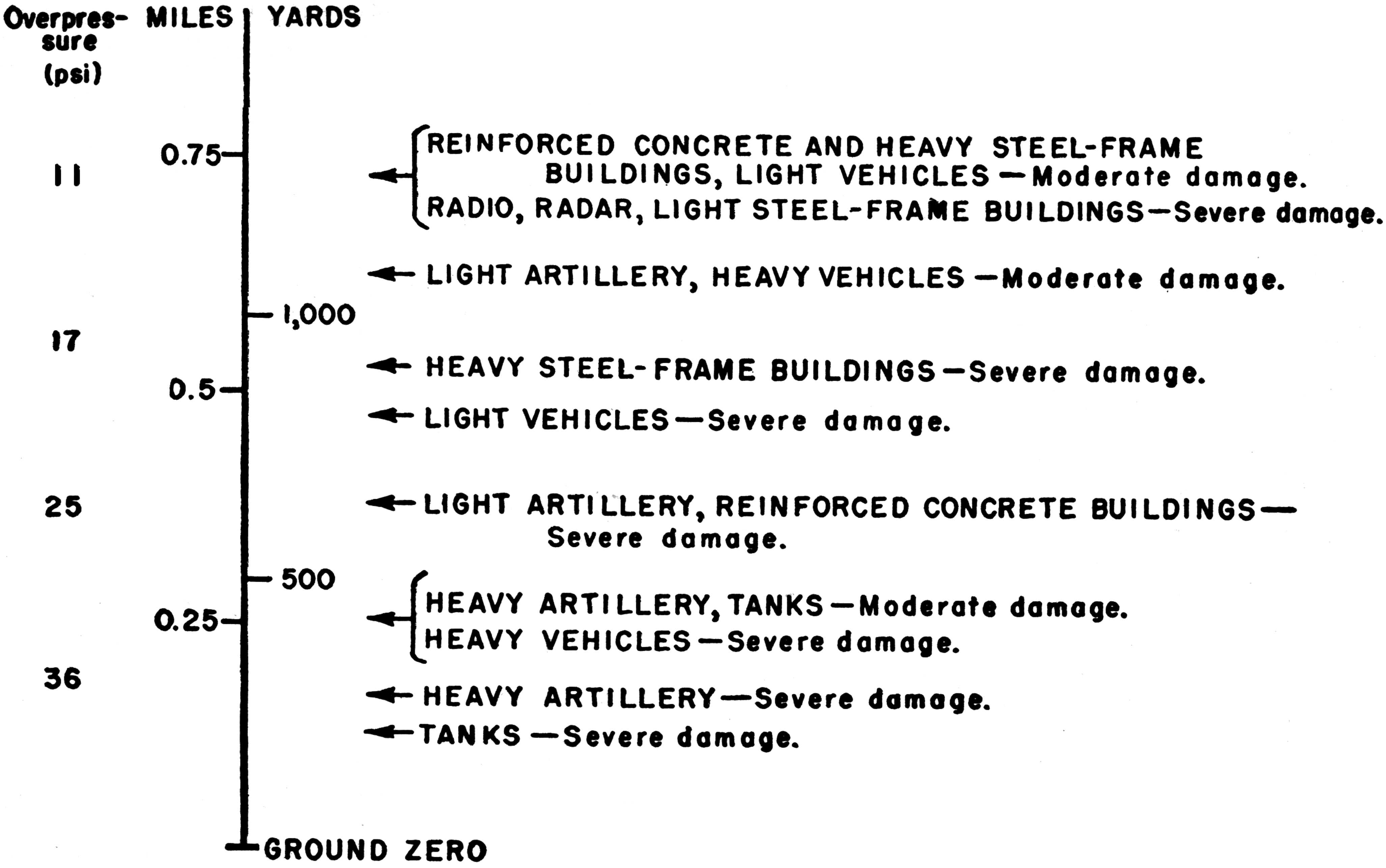

Table 6.59. nominal atomic bomb at 2,000 feet altitude.

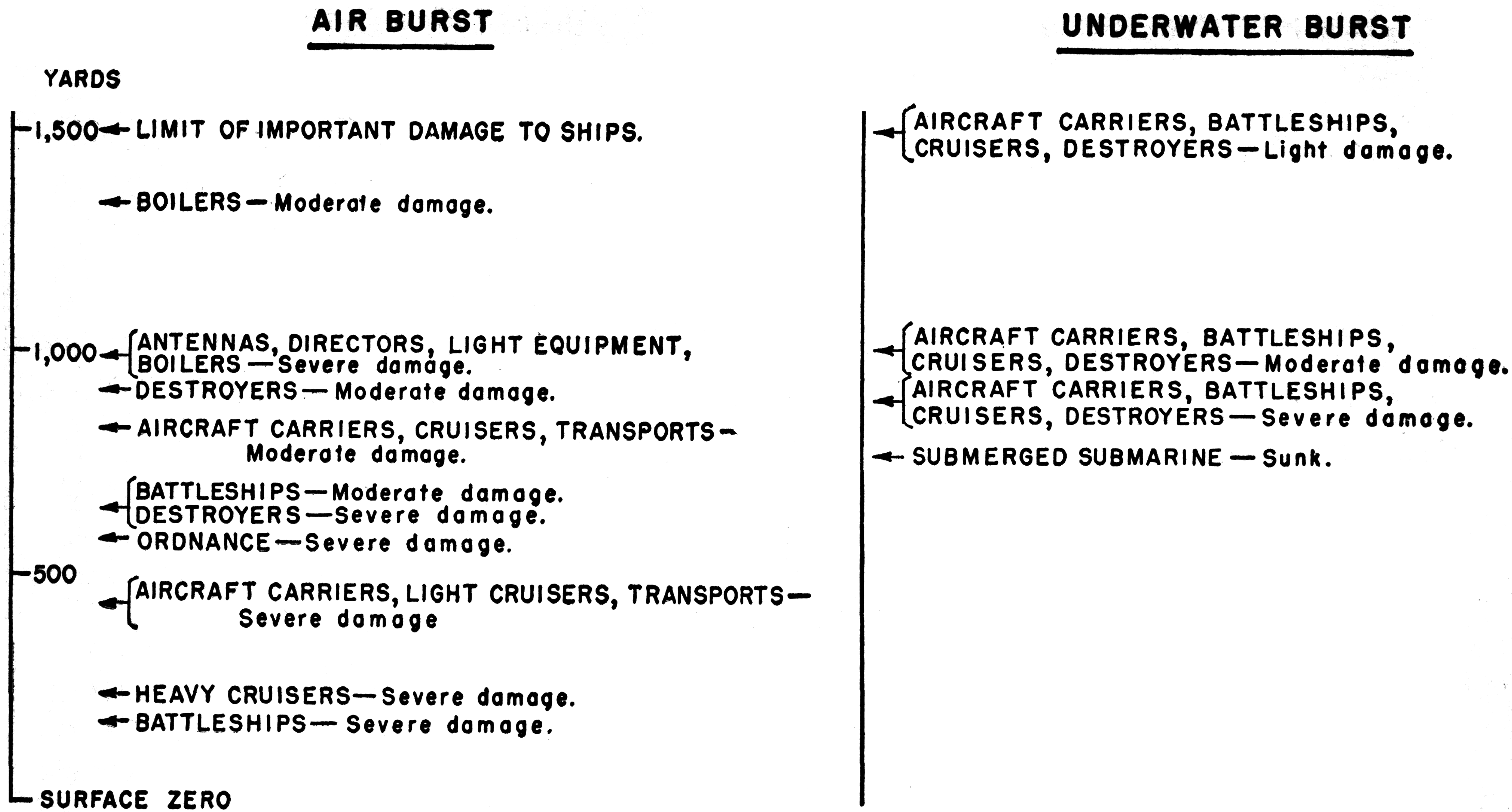

Table 6.92. Comparison of damage ranges to ships, due to air burst at 2,000 feet altitude and shallow underwater burst of a nominal atomic bomb.

Figure 10.37. Tunnel shelters in hillside, very close to ground zero in Nagasaki, protected the occupants from blast, thermal radiation, and immediate nuclear radiation.

Figure 12.96. Rough decontamination of the NEW YORK, after Test Baker at Bikini, by hosing down with sea water from a Navy rescue tug.

12.99. Following an underwater burst the base surge will constitute a possible hazard. However, if the interior of the ship is water-tight and the ventilation system is shut down completely, the entry of the base surge can be prevented. Since about a minute will elapse before the base surge overtakes a moderately undamaged ship, there should be time for personnel to take appropriate cover and for the ship to be secured by closing all ventilation intakes, doors, and hatches. This is an operation which can be planned and practiced in advance, so that it can be performed as quickly as possible.

12.100. It was stated in paragraph 11.38 that if topside structures are wetted with sea water before an atomic attack, contaminated particles can subsequently be removed much more readily. It is expected that, where practicable, future ship design will make provision for a "water curtain" for flushing weather surfaces prior to an attack, and for subsequent possible decontamination. Generally, however, the ship's fire hoses may be used to drench all exposed topside surfaces. Trial experiments will indicate how quickly the wetting-down operation can be performed.

HISTORY OF THE SECOND WORLD WAR

Civil Defence

By

T. H. O'BRIEN

CIVIL DEFENCE

BY

TERENCE H. O'BRIEN

LONDON: 1955

HER MAJESTY'S STATIONERY OFFICE

AND

LONGMANS, GREEN AND CO

The point is of importance for students of the subject in an era in which marked 'progress' has been made in the technique of air warfare by the invention of the atomic bomb. This invention has given fresh currency to the view that 'nowadays every war is different from the one before'—which, if it were valid, would abolish any need to learn the lessons of past experience.

But in May 1917 the Germans began a series of assaults with twin-engined aircraft, called *Gothas*, which soon became severe. The daylight attack of 13th June on London by fourteen *Gothas* was the worst single attack of the war measured in casualties, which numbered 162 killed and 426 injured; 118 high explosive and incendiary bombs were dropped on the City and the East End.

The Government only gave in gradually and reluctantly to demands for public warnings in London. In July 1917 a system was introduced, under the control of the Commissioner of Police, which to those accustomed to the sirens of 1939–45 may appear somewhat primitive. Warnings were distributed partly by maroons (or sound bombs) fired into the air, and partly by policemen on foot, on bicycles or in cars carrying *Take Cover* placards and blowing whistles or sounding horns.

during 1914–18 There were in all 103 bombing raids (51 by airships and 52 by aeroplanes); and about 300 tons of bombs were dropped causing 4,820 casualties, 1,413 of which were fatal.

These totals appear small; but when they are broken down into details many different pictures emerge. The two heavy raids on London of June and July 1917, for example, together caused 832 casualties (216 fatal), which amounted to 121 casualties for each ton of bombs dropped; and these casualty figures were to have much significance for the planning authorities of the future.

13 June London raid: 118 bombs, 162 killed, 426 injured.
7 July London raid: 54 killed, 190 injured

121 casualties/ton, 31 killed/ton
(Air raids by twin-engined Gothas began in May 1917)

The Committee of Imperial Defence, created in 1904

In November 1921 the Committee asked the principal Service experts to report on the problem of possible future air attack on the United Kingdom. This report, which appeared the next year, accepted the conclusions of the Air Staff about future air attack, which were briefly as follows.

France's Air Force could drop an average weight of 1,500 tons of bombs on Britain each month by using only twenty bombing days in the month and only fifty per cent of its aircraft. London, which would be an enemy's chief objective, could be bombed on the scale of about 150 tons in the first 24 hours, 110 tons in the second 24 hours, and 75 tons in each succeeding 24 hours for an indefinite period. It was to be anticipated that an enemy would put forth his maximum strength at the outset.

Page 14: on 15 May 1924, the Air Raid Precautions (ARP) Sub-Committee first met, chaired by Sir John Anderson.

The serious picture thus presented assumed its darkest tones when the Air Staff proceeded to estimate casualties. The 300 tons of bombs dropped in the 1914–18 attacks, the experts pointed out, had caused 4,820 casualties, or 16 per ton of bombs. The 832 casualties of the two big daylight attacks on London in the summer of 1917, however,

produced an average of 121 casualties per ton; and sixteen night raids on London in 1917–18 gave an average of 52 casualties per ton.[1] After weighting these figures with various factors, the experts concluded that 50 casualties (one-third of which would be fatal) per ton formed a reasonable estimate of casualties caused by air attacks of the future on densely-populated areas. For other areas this figure should be reduced in proportion to the actual density of population.

In March 1927 the committee was faced with two matters

Royal Charter incorporating the British Broadcasting Corporation, *Wireless Broadcasting*, Cmd. 2756, 1926.

The Chemical Warfare Research Department had been making experiments to determine how long persons could remain under certain conditions in a 'gas-proof' room; and had prepared a handbook, *The Medical Aspects of Chemical Warfare*, now on sale to the public.

The first of the matters just referred to was a broadcast in February by Professor Noel Baker, on 'Foreign Affairs and How They Affect Us'. This, read in cold print at a distance of twenty years, appears as an attempt to rouse the British public to realisation of the horrors of future war, and to enlist its support for the disarmament negotiations at Geneva. The Professor quoted Mr Baldwin's speech to the Classical Association in the Middle Temple hall, 'Who in Europe does not know that one more war in the West and the civilisation of the ages will fall with as great a shock as that of Rome?' He painted a picture of gas attack from the air in another war and claimed, 'all gas experts are agreed that it would be impossible to devise means to protect the civil population from this form of attack'. The Chemical Warfare Research Department emphatically disputed the accuracy both of the details of the picture and of this general statement. They considered it unfortunate that statements of this nature should have been broadcast to the public, particularly after the Cabinet's decision that the time was not ripe for education of the public in defensive measures.

The committee discussed whether to draw the B.B.C.'s attention to this talk. The Corporation, only a few months old, was then prohibited by the Postmaster-General's instructions from broadcasting 'matter on topics of political, religious or industrial controversy'; but the Post Office representative pointed out this did not mean that his Department was prepared to undertake censoring programmes. The committee, not wishing to incur the obligation to approve in advance all proposed broadcasts relating to their field of study, decided to take no action with respect to the talk in question.

Gas was the risk most prominently associated in the public mind with future air attack, as was demonstrated a few weeks before the school opened by British reaction to Italy's use of mustard and other gases against Abyssinia.[4]

[4] According to the *Annual Register, 1936* (p. 27), 'feeling in England could hardly contain itself when the Italians were reported to be using poison gas against both soldiers and civilians'.

A final matter which concerned gas-masks belongs perhaps more properly to the topic of public reactions to A.R.P. Early in 1937 some scientific workers at Cambridge University, who described themselves as the 'Cambridge Scientists' Anti-War Group' and their function as that of acting as 'a technical and advisory body to national and international peace movements', published a book attacking the Government's A.R.P. plans.[1] This body had studied the official advice about the 'gas-proofing' of rooms, the civilian mask, and extinguishing incendiary bombs, and then conducted some experiments. It claimed to have shown that the measures officially proposed were ineffective or inadequate, and implied that these constituted deception of the public.

It has been noticed that as 1937 opened the Government was taking steps to make A.R.P. plans more widely known to the public;[2] and this deliberate challenge found a sympathetic echo in various quarters, and caused it some concern. Questions about the Cambridge experiments were asked in Parliament, for example on the occasion of the announcement of the new Wardens' Service; sections of the Press began a critical campaign, and questions were put to officials trying to build up A.R.P. services over the country. The Government's reply was that the experiments were academic (in the sense of removed from reality), and based on fallacious assumptions about the conditions likely to be met in actual warfare.[3] In spite of pressure the authorities refused to engage in technical controversy with the scientists in question and within a few months the agitation subsided. At the close of the year, however, a report on the official experiments (in supervision of which the Chemical Defence Committee had been helped by eminent scientists not in Government employment) was circulated to local authorities and otherwise made public.

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[1] *The Protection of the Public from Aerial Attack* (Left Book Club Topical Book, Victor Gollancz Ltd, 1937.)

[2] p. 71.

[3] H. of C. Deb., Vol. 320, Col. 1348, 18th February 1937.

A demonstration of how to deal with the light incendiary bomb had been included in the Anti-Gas School curriculum in November 1936; and in February 1937 the Home Office Fire Adviser staged a demonstration at Barnes at which bombs were successfully controlled and fires extinguished by teams of girls with only short training. At an exercise held later at Southampton a group of air raid wardens carried out this function with such success that the Department concluded it must aim to train all householders in the handling of incendiary bombs.

Air Staff had raised their estimate of the weight of bombs which an enemy (now Germany) might drop on Britain during the first stages of an attack from 150 tons *per diem* to no less than 600 tons. The committee proceeded, as their predecessor of 1924 had done, to question the experts and then to accept their hypothesis.[1] The estimate of over 600 tons of bombs *per diem* during the first few weeks (which took account of Britain's various potential forms of counter-offensive) also embraced the possibility of a special bombing effort on the part of the enemy in the first 24 hours which might amount to 3,500 tons. Consideration had to be taken not only of this greatly increased weight of attack but of new methods of attack for which past experience afforded no precedents. The measure offered by the accepted air raid casualty figure of 1914–18 (50 per ton of bombs, 17 of which were killed and 33 wounded) was subject to the *caveat* that modern bombs were more effective. The committee pointed out that an arithmetical computation on this basis for the scale of attack at 600 tons *per diem* would indicate casualties of the order of 200,000 a week, of which 66,000 would be killed.

---

[1] The new estimated scale of attack had been referred to the Home Defence Committee, and was not approved by the Committee of Imperial Defence until 28th October 1937.

The 25 million civilian gas-masks accumulated by the opening of 1938 were, from various points of view, one of the most tangible assets of the A.R.P. Service.

The invention of a practical household shelter—to be quickly known as the 'Anderson'—had transformed the possibilities hitherto envisaged for protection of homes against air attack. The Government had undertaken to supply these shelters, as well as steel fittings for strengthening basements, free to some 2½ million families.

The 'Anderson' had originally been conceived as a shelter to be erected inside the average small working-class home. But the experts soon discarded this idea as open to various objections, including the probability that occupants would be trapped by the fall of their house and killed by fire or escaping coal-gas. During Munich householders had been advised to dig trenches in their yards or gardens, and now, by an extension of this plan, the 'Anderson' was designed as an outdoor or surface shelter. It consisted of fourteen corrugated steel sheets weighing, with other components, about 8 cwt. A corrugated steel hood, curved for greater strength, would be sunk some two feet in the ground and covered with earth or sandbags.

The programme for manufacture and distribution by the end of 1939–40 of 2½ million 'Andersons' to protect about 10 million citizens was being steadily carried through.

householders in May in the form of a booklet, *Your Home as an Air Raid Shelter.*[1] This stated that an ordinary soundly-built house would offer very substantial protection; and it gave those unable to build some form of shelter much detailed guidance on the preparation of refuge rooms, the protection of windows and so on.

[1] H.S.C. 98/40, 22nd May 1940.

16 April 1941: heaviest London air raid of WWII:

On the night of 16th-17th some 450 aircraft made the heaviest raid so far on the capital, dropping 446 tons of high explosive and 150 tons of incendiaries and causing more casualties—about 1,180 killed and 2,230 badly injured—than in any previous attack.[1] Over 2,250 fires were started; and the centre and south of the metropolis bore the brunt of the attack.

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[1] German records show the much higher figures of 685 aircraft, 890 tons of H.E. and 4,200 incendiary canisters dropped. This attack proved the worst on London of the war in terms of weight of bombs dropped, casualties inflicted and the number of fires caused.

 1943:

These occasions apart, the attack was predominantly of the tip and run or—as it was sometimes called—'the scalded cat' variety. The worst single incident of the year took place on 3rd March at Bethnal Green Tube shelter when, ironically enough, no attack was in progress on this particular area. A night attack of moderate proportions was being made on London, and warnings had sounded. A woman among the crowd entering this shelter, encumbered by a baby and a bundle, fell, causing those pressing behind her to tumble in a heap and the death by suffocation of no less than 178 persons. **3 March 1943**

In London a periodical count was made of shelterers, usually once a month; but this took place on a single night which was not necessarily typical. In addition, the population was continually fluctuating owing to evacuation, the call-up to the Forces and war damage. The first shelter census in Metropolitan London, taken early in November 1940, showed that 9 per cent. of the estimated population spent the night in public shelters, 4 per cent. in the Tubes and 27 per cent. in household shelters—in all, only 40 per cent. in any kinds of official shelter. In September and October this proportion was probably a good deal higher. Later, as the London public became accustomed to raids, the figures dropped.

Experience of raids also led to the introduction of an entirely new type of household shelter. 'Andersons', though structurally satisfactory, had not originally been intended for sleeping and became in many cases unfit for winter occupation. Domestic surface shelters were very cramped when used for sleeping and were in some places not popular, and strengthened domestic basements had been neither very successful nor widely used. After night raiding had ceased to be a novelty, many people preferred to stay in their houses rather than to go out of doors even to their own domestic shelters. The 'Anderson', it will be recalled, had at first been envisaged as an indoor shelter. Since many people were now determined to remain in their homes, it had become necessary to introduce some indoor shelter which might reduce the risk of injury from falling masonry and furniture. The fact that many who had hitherto sheltered under their staircases or furniture had been rescued unhurt from the wreckage of houses suggested that extra protection might be given by a light structure on the ground floor.

By the end of 1940 two designs had been produced. The first, later known as the 'Morrison' shelter, had a rectangular steel framework 6 ft. 6 in. long, 4 ft. wide and about 2 ft. 9 in. high. The sides were filled in with wire mesh, the bottom consisted of a steel mattress and the top was made of steel plate an eighth of an inch thick, fastened to the framework by bolts strong enough to withstand a heavy swinging blow. The shelter, which could be used as a table in the daytime, could accommodate two adults and either two young children or one older child, lying down. Experiments showed that it would carry the debris produced by the collapse of two higher floors.

The Prime Minister showed great interest in these shelters the first of which, in fact, were erected in No. 10 Downing Street.[2] In January 1941 the Cabinet approved the manufacture of 400,000, providing protection for perhaps 1,200,000 people.[3]

In February contracts had been placed for 270,000 shelters, and another order for the same number was placed in April (thus exceeding the 400,000 originally approved). Two further orders for 270,000 were placed at the end of July and the end of September.

---

[1] Instructions were given in a pamphlet, *How to put up your Morrison shelter*, on sale to the public.

[2] One with a flat top and one with a curved top were erected in No. 10 Downing Street. The Prime Minister was at first inclined to favour the curved design but he afterwards recognised the advantages of the flat top, which would allow the shelter to be used as a table, and gave his approval to both designs.

[3] It was estimated that each 'Morrison' would use over 3 cwt. of steel, and that about 65,000 tons would be needed for the 400,000 shelters. This proved to be an under-estimate since the table shelter, as finally designed, actually weighed 4.43 cwt.

In June a revised version of *Your Home as an Air Raid Shelter* was issued with the title *Shelter at Home*. This included information about three types of shelter which could be put inside refuge rooms—the 'Morrison', a commercially made steel shelter, and a timber-framed structure designed by the Ministry of Home Security.

546 *Ch. XII: SHELTERS*

It was assumed that to be effective in attacks by pilotless aircraft or long-range rockets, shelters would have to be easily accessible. Yet a review of London shelter in the summer of 1943 had shown that large numbers still had no domestic shelter, and that many thousands would be unable to reach a public shelter quickly. Though the obvious solution to the problem was the 'Morrison', production of these had stopped twelve months before; and in order to build up a reserve issue had been discontinued in various areas, including London. At the beginning of October it was decided that another 100,000 'Morrisons' should be manufactured and that the reserves held in Scotland, the North of England, the Midlands and North Wales should be moved to the vicinity of London and to the Reading and Tunbridge Wells Regions, from where they could, if necessary, be used to supply London.

Large-scale redistribution of 'Morrisons' and the procurement of new ones called for a substantial administrative effort. Nonetheless, most reserves were transferred during the autumn, and by the end of January 1944 some 12,000 had deen distributed to London householders. At the beginning of this year, however, preparations for the Allied invasion of Europe began to choke the railways with more important traffic, and it became impossible to transport new shelters from manufacturers in the north of England. This difficulty, combined with delays in the production of spanners and nuts, meant that no new shelters could be delivered before late February or early March, when it was expected that the V-weapon attacks would have begun. Arrangements were made for some to be shipped coastwise to London; but in mid-February the contract for the remaining 'Morrisons' (about 20,000) was cancelled.

V2 THREAT:

648 *Ch. XV: CHALLENGE OF 'V' WEAPONS*

On 11th September the War Cabinet considered the need for a revival of the plan (known as the 'black move') to evacuate a proportion of the staffs of Government Departments from London. The numbers now involved in such an exodus of the war-expanded Departments would be high, and difficulties of communications, transport, accomodation and billeting again seemed overwhelming; it was, therefore, agreed that the more practical course would be to devise measures such as 'citadel' accommodation to enable essential work to continue in London. The production of the further 100,000 'Morrison' shelters and the work on the reinforcement of street shelters proposed by the Home Secretary were also authorised.

As far as shelter policy was concerned, orders had been placed in September 1943 for an additional 100,000 indoor table shelters and existing stocks were moved into the areas of probable attack. Difficulties of manufacture and transport had led to poor deliveries of 'Morrisons', and it seemed unlikely that more than half of the additional shelters ordered would be available by the time attacks were likely to begin. As the remainder would probably arrive too late to be of any use, contracts for the shelters were to be reduced by about 25,000. On the question of deep Tube shelters it had been agreed earlier that priority in the allocation of space would have to be given to the essential machinery of government. The Ministry of Works worked out a plan to shelter those government staffs not already provided for in the strengthened basements of their own steel-framed buildings. All shelter plans, the reader will recall, were given valuable impetus by the resurgence of 'conventional' attack on London and the south in the 'Little Blitz' of early 1944.

V1 flying bomb:

Flying glass was a special danger and people were warned to take cover on the sound of a bomb diving or the engine stopping, and later on the sounding of imminent danger warnings. The vast damage to houses inevitably caused great domestic upheavals. To begin with there was a definite decline in production in London, due to an increase in the rate of absenteeism, to loss of time in actual working hours through workers taking shelter and to lowered efficiency through loss of sleep and anxiety. The extension of the industrial alarm system and the increase in the labour force repairing damaged property, however, soon reduced these early signs of disturbance. Within a few weeks evacuees were returning to London, shelters were less full and most people were going about their normal tasks as usual.

For the civil defence services the new weapon demanded new tactics. In many ways these attacks were much easier to contend with than ordinary bombing. Firstly, most of the incidents were isolated, so that services could be directed in strength to the affected area without constant competing demands on the personnel at every turn. Secondly, the fall of the bombs could be spotted within a matter of seconds by high-placed observation posts either by night or by day, so that rescue and first aid squads could be on the spot very quickly. Thirdly, the penetrative power of this weapon was slight so that incidents rarely involved the complications of broken gas, electricity or water mains, and there was also little tendency for fires to break out. On the other hand the bombs could fall at any time in crowded thoroughfares; the proportion of casualties in the streets was much higher than ever before while the proportion of trapped casualties was lower. At night time, since there were no German eyes above, the use of artificial light was less restricted and searchlights could be used for rescue work.

APPENDIX V

Total numbers of flying-bomb and long-range rocket incidents reported

Table 1—By Counties

Counties	Flying Bombs	Long-Range Rockets
London (Region)[1] .	2,420	517
Kent	1,444	64
Sussex . . .	886	4
Essex	412	378
Surrey . . .	295	8
Suffolk . . .	93	13
Hertfordshire . .	82	34
Hampshire . . .	80	—
Buckinghamshire . .	27	2
Norfolk . . .	13	29
Berkshire . . .	12	1
Bedfordshire . .	10	3
Lancashire . . .	8	—
Yorkshire . . .	7	—
Cheshire . . .	6	—
Cambridgeshire . .	5	1
Northamptonshire .	4	—
Oxfordshire . .	4	—
Isle of Ely . . .	3	—
Derbyshire . . .	3	—
Huntingdonshire . .	2	—
Lincolnshire . .	2	—
Durham . . .	1	—
Nottinghamshire . .	1	—
Leicestershire . .	1	—
Rutland . . .	1	—
Shropshire . . .	1	—
Total . .	5,823[2]	1,054[2]

[1] London Region received 41 per cent. of flying-bombs, and 49 per cent. of long-range rockets.

[2] 271 of these flying-bombs and 4 of the long-range rockets fell in the sea.

APPENDIX IV

Major night attacks on United Kingdom cities and towns from 7th September, 1940 to 16th May, 1941

Target Area	*Number of Major Attacks*[1]	*Tonnages of H.E. Aimed*
London	71	18,291
Liverpool-Birkenhead	8	1,957
Birmingham	8	1,852
Glasgow-Clydeside	5	1,329
Plymouth-Devonport	8	1,228
Bristol-Avonmouth	6	919
Coventry	2	818
Portsmouth	3	687
Southampton	4	647
Hull	3	593
Manchester	3	578
Belfast	2	440
Sheffield	1	355
Newcastle-Tyneside	1	152
Nottingham	1	137
Cardiff	1	115

[1] The enemy's definition of a 'major attack', i.e. one in which 100 tons or more of high-explosive bombs were successfully aimed at the target, has been adopted for this table.

Printed for the War Cabinet. May 1941.

MOST SECRET.

Copy No. 58

W.P. (G) (41) 44.

May 5, 1941.

TO BE KEPT UNDER LOCK AND KEY.

It is requested that special care may be taken to ensure the secrecy of this document.

WAR CABINET.

AIR RAIDS ON LONDON, SEPTEMBER–NOVEMBER 1940.

Memorandum by the Home Secretary and Minister of Home Security.

Framed buildings.

Most valuable information has been gained on the effects of bombs on framed buildings. Such buildings are practically immune to anything but a direct hit. Blast damage from bombs outside is usually confined to windows and internal partitions. Even parachute mines falling immediately outside the building or exploding on the roof produce negligible damage to structure or floors.

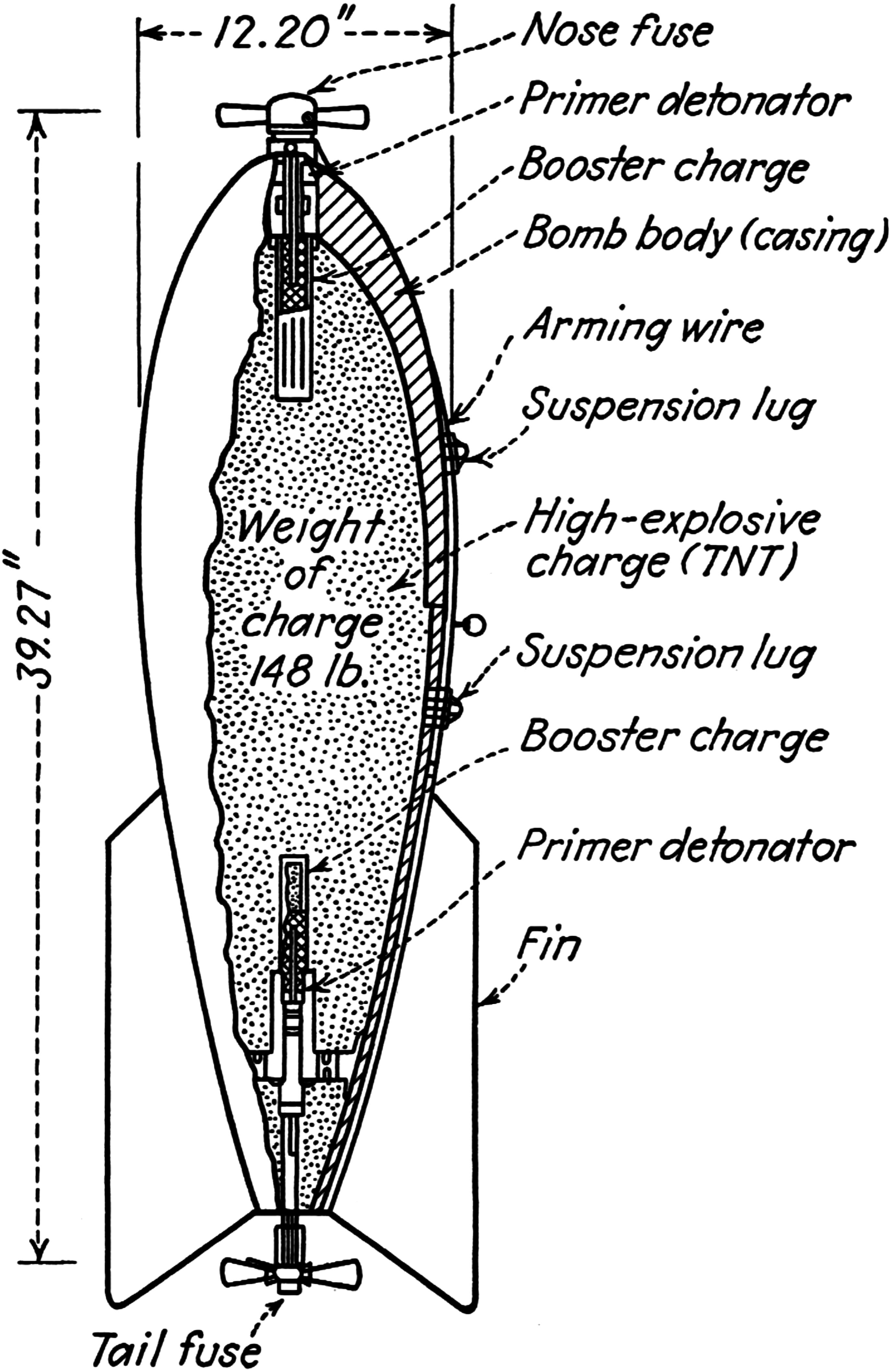
Relation of Casualties to Bombs Dropped.

From a knowledge of the number of bombs dropped and the casualties occurring in different boroughs, some idea can be gained of the effectiveness of bombs in producing casualties. The number of casualties per bomb varies widely from 1·59 in the least to 6·94 in the most populated boroughs, but it follows closely the apparent densities of population as shown in figure 1. The number of casualties per bomb is roughly a twelfth of the number of persons per acre, and the number of deaths per bomb about 1/60th of the number of persons per acre. From this it can be deduced that the mean distance at which injury from a bomb is likely to occur is 35 ft., and that at which the bomb is lethal is 15 ft.

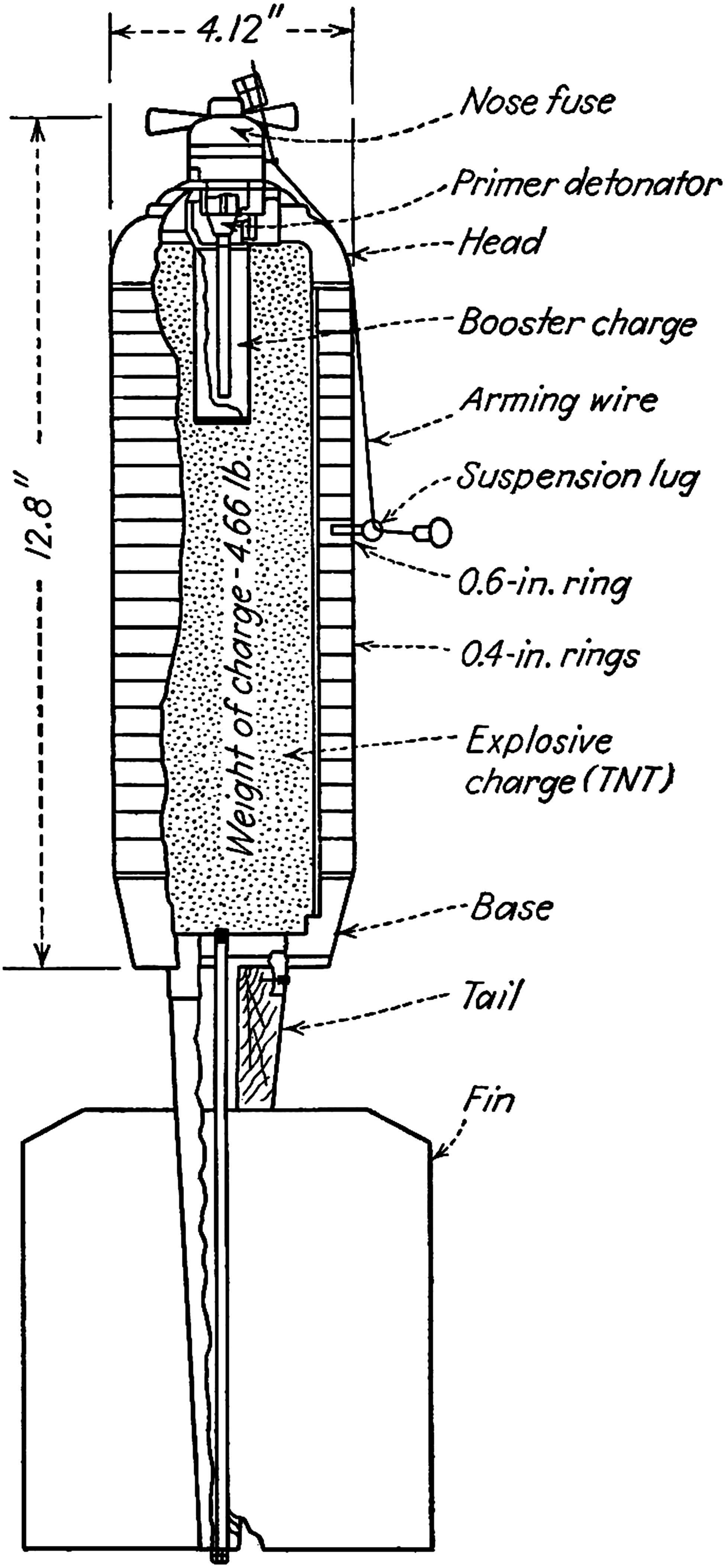
The casualties per bomb in Central London fell steadily from an average of 3·7 in September to 2·7 in October and 1·7 in November. This corresponds to the considerable fall in population in most of the boroughs concerned.

Conclusion.

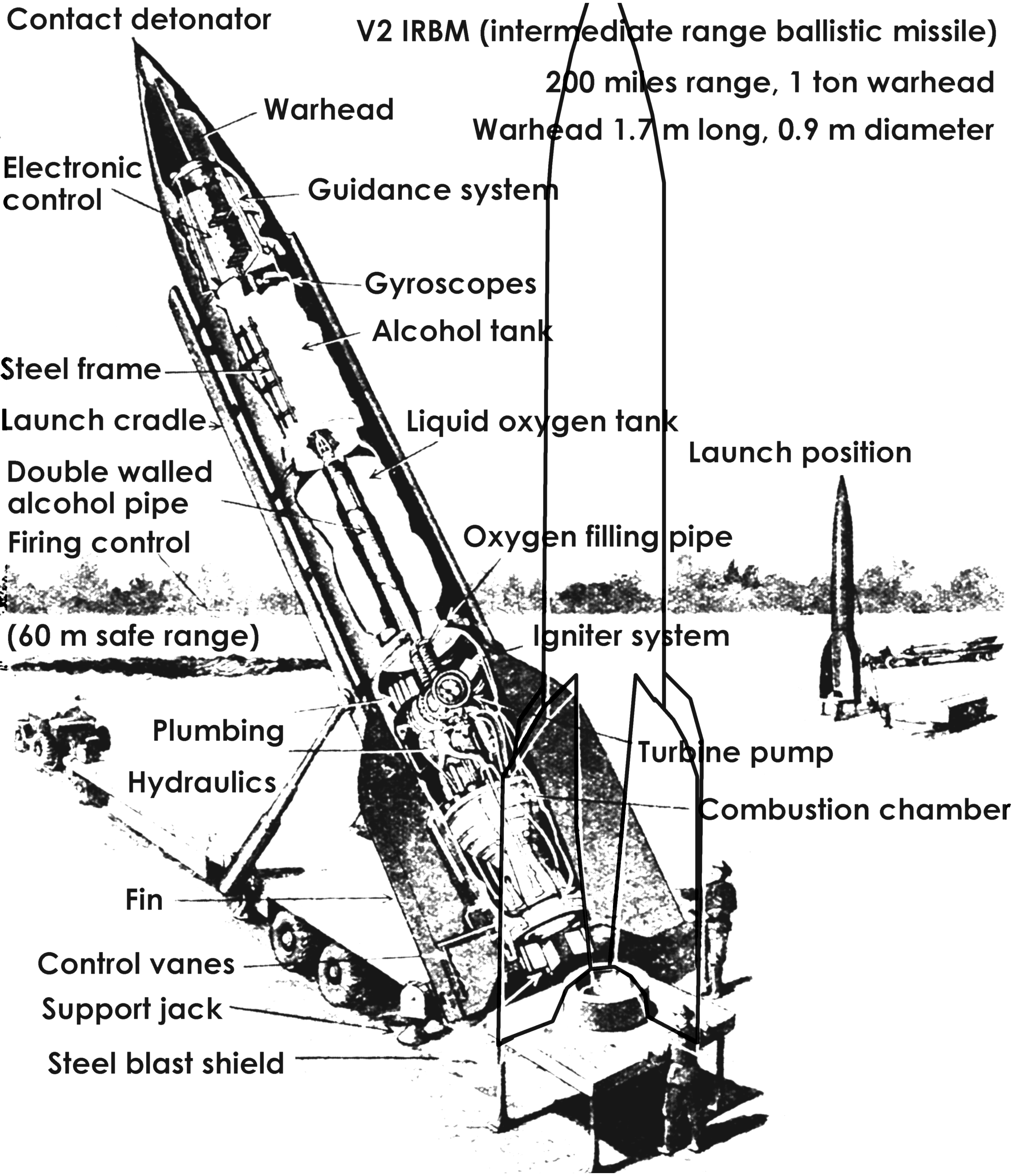
We may now say that we have a good general understanding, both qualitative and quantitative, of the effects of bombs on buildings and on cities. New types of bombs, particularly heavier bombs, may be used, but we can anticipate no startling change in the effects apart from increase in minor damage. With bombing of the present type the results of our work are to show that in urban areas, such as that of the County of London, *for one ton of bombs approximately* 10 *houses will be destroyed or will need pulling down.* 25 *more will be temporarily uninhabitable, and another* 80 *will be slightly damaged.* 80 *people will be made temporarily homeless and* 35 *will lose their homes permanently.* 25 *people, mostly among the latter category, will be wounded, the greater part of them slightly, and* 6 *will be killed or die from wounds.*



General purpose bomb (300 lb.)



Fragmentation bomb (30 lb.)


V2 IRBM (intermediate range ballistic missile)
200 miles range, 1 ton warhead
Warhead 1.7 m long, 0.9 m diameter
Contact detonator
Warhead
Electronic control
Guidance system
Gyroscopes
Alcohol tank
Steel frame
Launch cradle
Liquid oxygen tank
Launch position
Double walled alcohol pipe
Firing control
(60 m safe range)
Oxygen filling pipe
Igniter system
Plumbing
Turbine pump
Hydraulics
Combustion chamber
Fin
Control vanes
Support jack
Steel blast shield

V-2 ATTACK at Smithfield Market, London, where 110 people were killed and 123 seriously injured when pavements were crowded

THE UNITED STATES

STRATEGIC BOMBING SURVEY

THE EFFECTS OF STRATEGIC BOMBING ON GERMAN MORALE

VOLUME I

Morale Division

Dates Of Survey:

March - July, 1945

Date of Publication:

May 1947

A major factor in the final break-down of German civilian morale was strategic bombing. It was not the only factor adversely affecting morale, but it did much to produce a mood of defeatism in the civilian population. By the end of 1944, strategic bombing had depressed a substantial percentage of the bombed population into apathy.

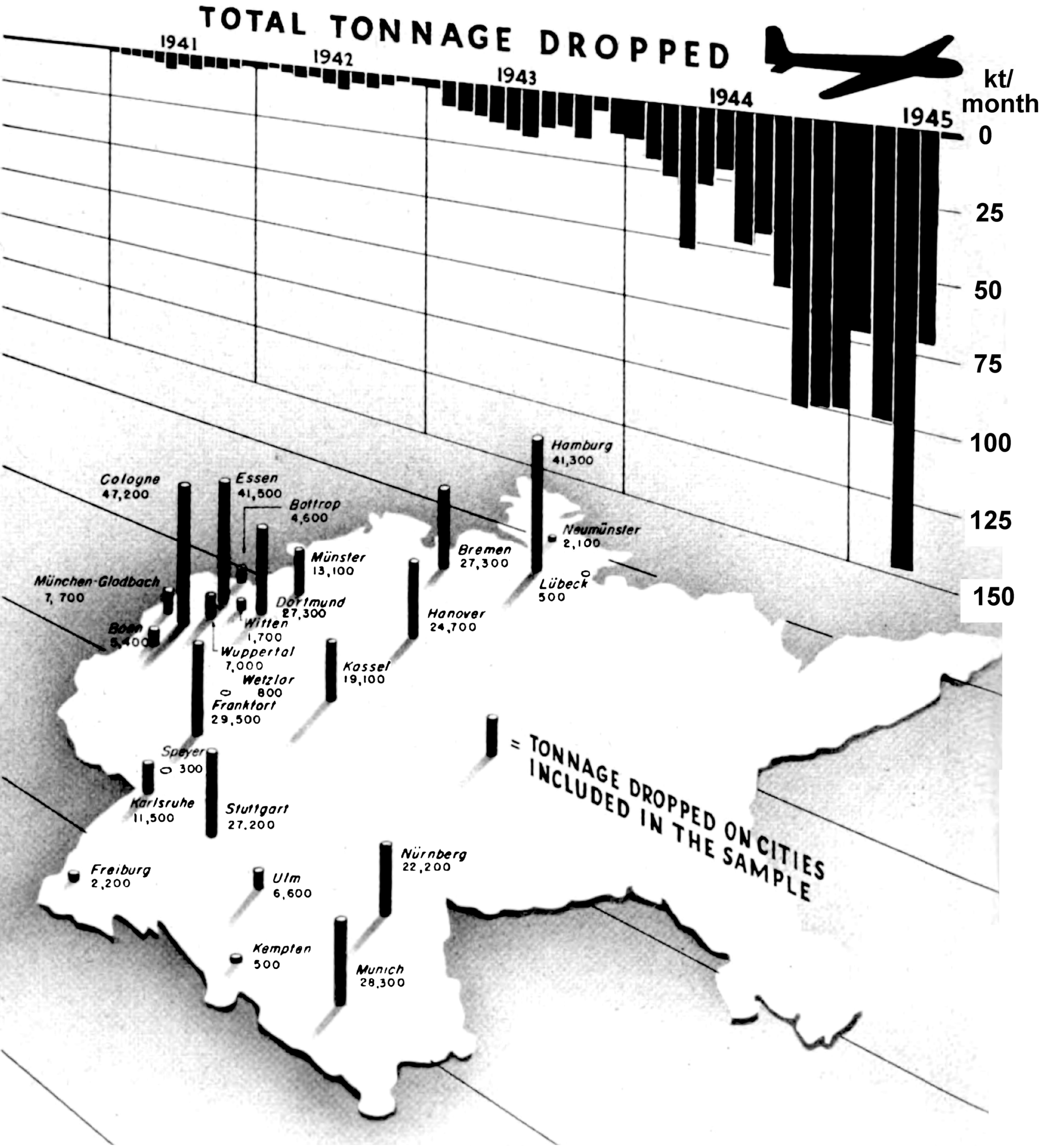
The reason that poor German civilian morale did not translate itself into action seriously endangering the German war effort until the latter months of 1944 and the early months of 1945 was largely due to the terroristic control of the population by the Nazis and, in part, to the cultural patterns of the German people.

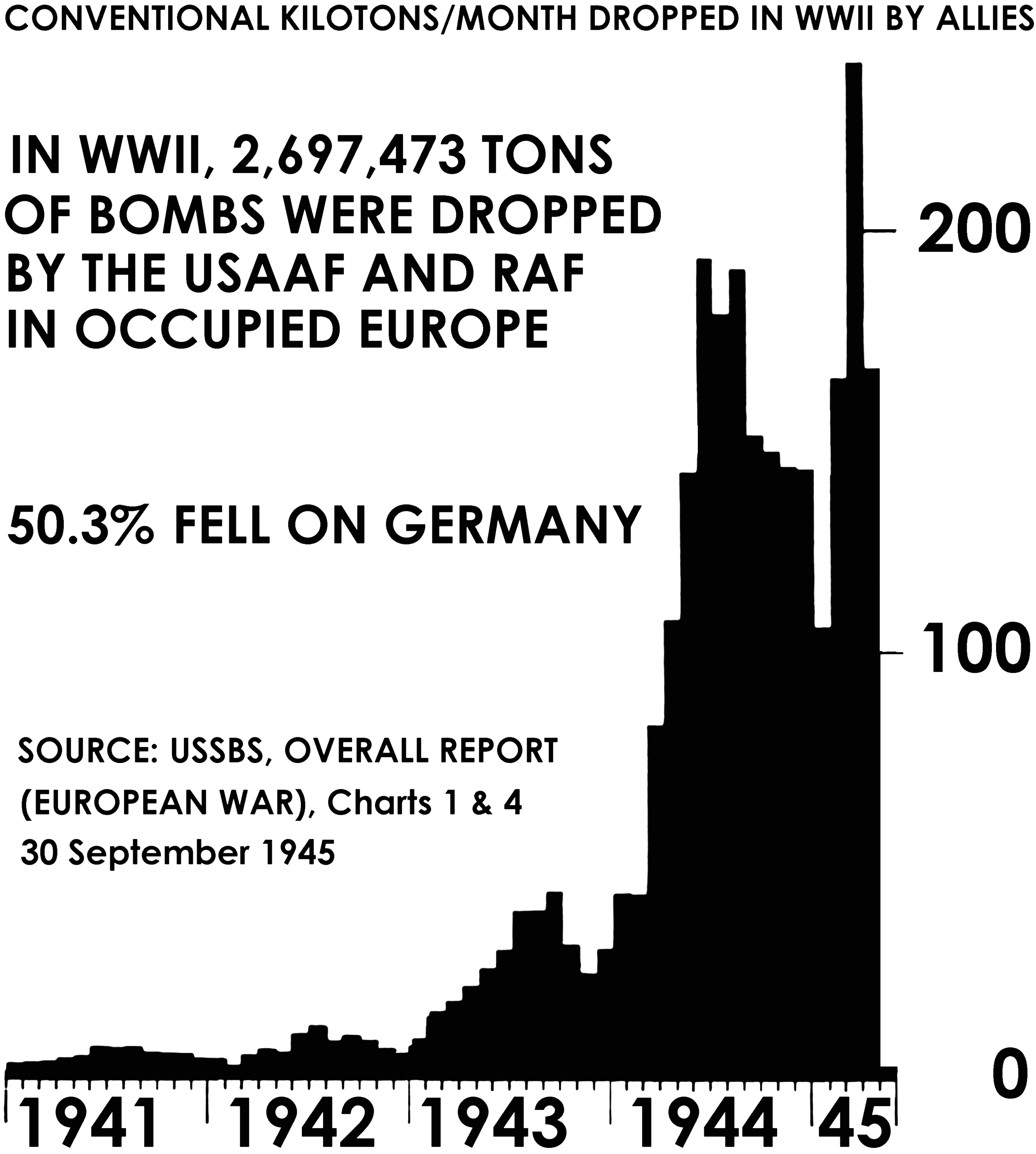
TABLE 1.—*Physical effects of bombing* [1]

Killed	305,000
Wounded	780,000
Homes destroyed	1,865,000
Persons evacuated	4,885,000
Persons deprived of utilities	20,000,000

[1] All estimates include Russian-occupied Germany. The casualty estimates are based on interviews with civilians and do not include police officials, members of armed forces, displaced persons, people in concentration camps.

BOMBING ATTACKS ON GERMANY




CONVENTIONAL KILOTONS/MONTH DROPPED IN WWII BY ALLIES
IN WWII, 2,697,473 TONS OF BOMBS WERE DROPPED BY THE USAAF AND RAF IN OCCUPIED EUROPE
50.3% FELL ON GERMANY
SOURCE: USSBS, OVERALL REPORT (EUROPEAN WAR), Charts 1 & 4
30 September 1945
200
100
0
1941
1942
1943
1944
45

THE UNITED STATES

STRATEGIC BOMBING SURVEY

FINAL REPORT

Covering Air-Raid Protection and Allied Subjects in

JAPAN

Civilian Defense Division

Dates of Survey:

1 October 1945—1 December 1945

Date of Publication:

February 1947

EXHIBIT A–3.

Total tons of bombs dropped on Japan by U. S. Army Air Forces—By months

AIR FORCE

Date	Total	Incendiary
1944		
June	----------	----------
July	28	----------
Aug	183	55
Sept	5	----------
Oct	159	68
Nov	766	298
Dec	992	495
1945		
Jan	1,261	435
Feb	1,884	929
Mar	12,788	10,023
Apr	16,150	3,967
May	25,065	18,699
June	27,497	18,172
July	43,422	31,670
Aug. (15 days)	23,687	13,655
Totals	153,887	98,466

THE UNITED STATES

STRATEGIC BOMBING SURVEY

THE EFFECTS OF AIR ATTACK ON JAPANESE URBAN ECONOMY

SUMMARY REPORT

Urban Areas Division

March 1947

TABLE 5.—*Damage to urban areas*

Total built-up area	square miles	[1]411
Target area	do	[1]192
Area destroyed	do	[1,2]178
Total population		21,928,000
Bombs dropped (74 percent incendiary)	tons	121,458
Buildings destroyed		2,094,374
Persons killed		252,769
Persons injured		298,650
Persons rendered homeless		8,324,000
Planned evacuations		2,100,000

[1] Operational summary, Twentieth Airforce. Refers only to 66 cities which were targets of planned urban area missions.

[2] 43 percent total built-up area for 66 cities.

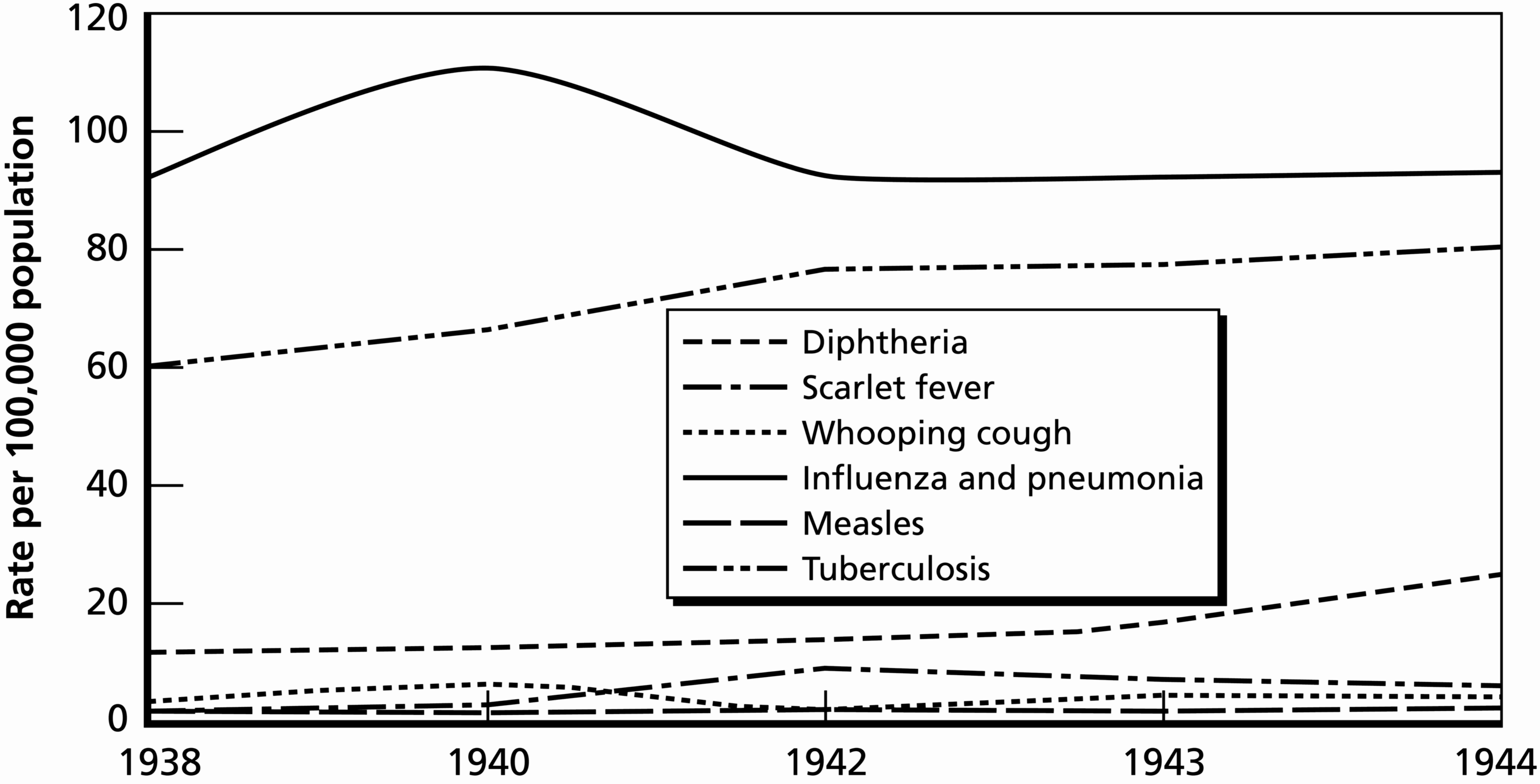
The cities of Japan, like those in Germany, presented a spectacle of enormous destruction. Although the over-all total damage was somewhat greater in Germany than in Japan the extent of destruction was comparable. Only 160,800 tons of bombs were dropped on Japan's home islands as compared with 1,360,000 tons dropped within Germany's own borders. One hundred and four thousand tons of bombs were dropped on 66 Japanese cities as compared with 542,554 tons of bombs that were dropped on 61 German cities.

As in Germany, the air attacks against Japanese cities were not the cause of the enemy's defeat. The defeat of Japan was assured before the urban attacks were launched. But this defeat, before it could be translated into the terms of surrender, might have required a costly invasion of the home islands had not the effect of the air attacks, both precision and urban, on Japan's industries and people exerted sufficient pressure to bring about unconditional surrender on 15 August. The city raids contributed substantially to that pressure by their impact on the social and economic structure of Japan.

The insufficiency of Japan's war economy was the underlying cause of her defeat. Before the air attacks against the cities began, war production had been steadily declining because of the ever-increasing shortages of raw materials, skilled labor, and an ill conceived dispersal program which was initiated too late. The Survey estimated that, even without air attacks, over-all production, by August 1945, would not have exceeded 60 percent and might have been as low as 50 percent of the 1944 peak.

Mortality Rate for Several Diseases, Germany, 1938–1944

Seth G. Jones, et al., "Securing Health", RAND Corp report MG321, 2006, Fig. 2.3



SOURCE: United States Strategic Bombing Survey, *The Effect of Bombing on Health and Medical Care in Germany*, pp. 30–105.

STANFORD RESEARCH INSTITUTE

STANFORD, CALIFORNIA

June, 1953

Final Report

IMPACT OF AIR ATTACK IN WORLD WAR II: SELECTED DATA FOR CIVIL DEFENSE PLANNING

Evaluation of Source Materials

By

Robert O. Shreve

SRI Project 669

Prepared for
Federal Civil Defense Administration
Washington, D. C.

Approved:

William J. Platt

William J. Platt, Chairman
Industrial Planning Research

Weldon B. Gibson

Weldon B. Gibson, Director
Economics Research Division

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 25 cents

Table 1

Report Outline - USSBS Project

IMPACT OF AIR ATTACK IN WORLD WAR II:
SELECTED DATA FOR CIVIL DEFENSE PLANNING

Division I - PHYSICAL DAMAGE TO STRUCTURES, FACILITIES, AND PERSONS

Volume 1 Summary of Civil Defense Experience
Volume 2 Analytical Studies (Restricted)
Volume 3 Causes of Fire from Atomic Attack (Secret) --VITAL!!

The documents which should be given wide distribution for civil defense use are listed below, with a brief description:

a. USSBS Reports

Effects of the Atomic Bomb on Hiroshima, Japan (3 volumes).

Effects of the Atomic Bomb on Nagasaki, Japan (3 volumes).

These reports constitute two case studies of atomic bombing. Civil defense planners should be aware of the facts these documents record in great detail. Their distribution to all civil defense planners and analysts is highly desirable.

-9-

Effects on Labor in Clydebank of Clydeside Raids of March 1941, (REN 234) USSBS Target Int.(REN 236) Ministry of Home Security

A study of the effects on labor of bombing in a town of 50,000 people in which 76% of houses were rendered uninhabitable, 73% of the population homeless. An equivalent of 65 city days was utilized in the reconstruction.

-22-

Ministry of Home Security
Effects of German Air Force Raids on Coventry (REN 441)

The city, the attack, casualties, repairs and reconstruction (cost), absenteeism, population movements, and housing occupancy. Six pages and charts and graphs. Twenty percent of houses rendered uninhabitable or destroyed, a total reconstruction cost of £ 3,492,000. Average time lost by worker after November raid was eleven days; average after April raid was 7 days. Nine percent of the workers evacuated to points within reach of the city.

STANFORD RESEARCH INSTITUTE

STANFORD, CALIFORNIA

June, 1953

Final Report

IMPACT OF AIR ATTACK IN WORLD WAR II: SELECTED DATA FOR CIVIL DEFENSE PLANNING

Division II: Effects on the General Economy

Volume 1: Economic Effects - Germany

Part One

SRI Project 669

Prepared for

Federal Civil Defense Administration
Washington, D. C.

Approved:

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Economics Research Division

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price $1.25

Over-all Report (European War). 109 pp. STRATEGIC BOMBING SURVEY

This volume recounts the history of the build-up of air power, showing the great increase in 1945. The results of attack on selected major industries in Germany are also considered. The report concludes that attrition caused the downfall of economy, especially as it affected transportation and oil.

LOGISTICS TARGETTED

Summary Report (European War). 18 pp. STRATEGIC BOMBING SURVEY

Germany planned a quick war; the Allies planned a long war and started a systematic attack on German industry. The British concentrated on area raids; the United States, on precision bombing. Ball bearings, aircraft, oil, steel, and transportation were attacked in order. The attack on transportation was the decisive blow that completely disorganized the German economy. Civilians withstood bombing fairly well, and the recuperation of German industry was surprising.

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Copy 162 of 300
ORO Log No. 56656

HOME DEFENSE DIVISION
PASSIVE DEFENSE GROUP
Report ORO-R-17, Appendix B
Published December 1956

Effectiveness of Some Civil Defense Actions in Protecting Urban Populations (u)

Appendix B of Defense of the US against Attack by Aircraft and Missiles (u)

by

John Balloch

Annex A *by* G. Trevor Williams

Annex B *by* Oscar Sutermeister

Authorized by

Ellis A. Johnson

Director

ORO

OPERATIONS RESEARCH OFFICE

The Johns Hopkins University Chevy Chase, Maryland

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LETHAL RANGE

The mortality coefficients vs distance of a 10-Mt weapon as used in this study are presented in Fig. 9. For comparison, mortality vs distance curves as used by the FCDA and SRI are also presented. All three curves are based essentially on Hiroshima-Nagasaki data and have been modified to account for the longer positive-pulse phase associated with

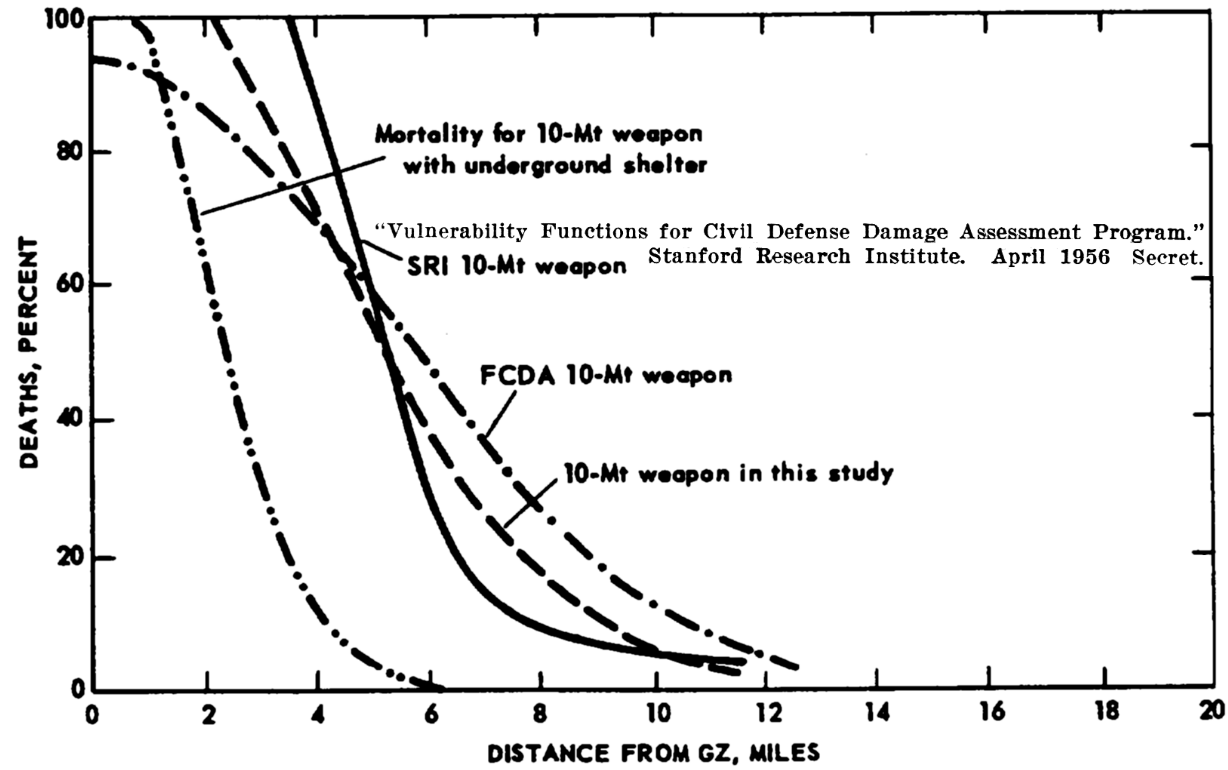


Fig. 9 — Population Lethality Contours for 10-Mt Ground Burst

high-yield weapons. The curve used in this study was the best approximation to Hiroshima data that would meet the purposes of the study; like the SRI curve it has a region of 100 percent mortality to meet the requirements of cratering associated with ground bursts.

Figure 9 also gives the mortality coefficients for populations in shelters with 3 ft of earth cover.

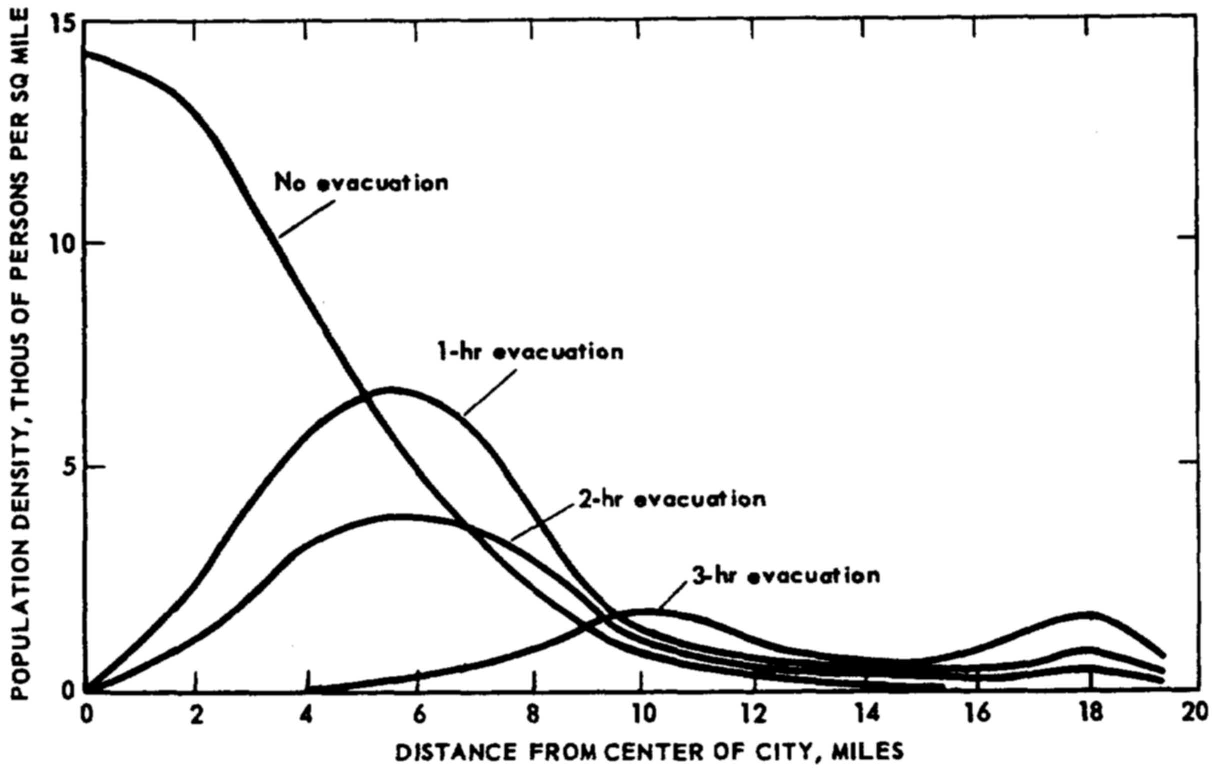


Fig. 10 — Population Density of Washington Target as Function of Distance from Center of City for Three Evacuation Times

BIOLOGICAL AND ENVIRONMENTAL EFFECTS OF NUCLEAR WAR

HEARINGS

BEFORE THE

SPECIAL SUBCOMMITTEE ON RADIATION

OF THE

JOINT COMMITTEE ON ATOMIC ENERGY CONGRESS OF THE UNITED STATES

EIGHTY-SIXTH CONGRESS

FIRST SESSION

ON

BIOLOGICAL AND ENVIRONMENTAL EFFECTS OF NUCLEAR WAR

JUNE 22, 23, 24, 25, AND 26, 1959

PART 1

Printed for the use of the Joint Committee on Atomic Energy

UNITED STATES
GOVERNMENT PRINTING OFFICE
43338 WASHINGTON : 1959

I have a chart (table 1) to which I would like to refer, Mr. Chairman, which summarizes these weapon sizes. As I indicated, there were 263 weapons used for a total weight of 1,446 megatons; 60 of these weapons were 10-megaton size for a total of 600. This chart illustrates the distribution of the other weapon sizes. There were 74 of 8 megatons for a total of 592, and, as you will see, there was a large weight in the higher weapons of 8 and 10 megatons reducing to 37 of the 2-megaton weapons and 48 of the 1 megaton, for a total attack of 1,446 megatons.

The next chart (table 2) shows the distribution by target; 111 of the targets were Air Force installations. Total weight 645 megatons. The size of the weapons used on Air Force installations varied; 71 of the targets were critical target areas. By this we mean concentrations of population and industry. They contain about 68 million of the country's population. One hundred and ten weapons were used against these areas for a total weight of 567 megatons. I will leave this chart up while I talk further, Mr. Chairman.

(The charts referred to are as follows:)

TABLE 1.—*Weight of the attack*

Size of weapon (megatons)	Number used	Weight of attack (megatons)
10	60	600
8	74	592
3	44	132
2	37	74
1	48	48
Total	263	1,446

TABLE 2.—*Targets of the attack*

Number and type of target	Number of weapons	Weight (megatons)
111 Air Force installations	111	645
71 Critical target areas	110	567
21 AEC installations	21	168
12 Army installations	12	24
5 Navy installations	5	28
4 Marine Corps installations	4	4
224, total	263	1,446

Representative HOLIFIELD. Mr. Quindlen, I think it would be well to bring out at this point the fact that the two bombs used over the Japanese cities were approximately 20,000 tons of TNT equivalent.

Mr. QUINDLEN. Yes, in that general area.

Representative HOLIFIELD. In that general area?

Mr. QUINDLEN. Yes.

Representative HOLIFIELD. So, when we talk about a megaton, we are talking about a million tons, and then we have to, in our mind, compare that with 20,000 tons which destroyed a city of some 100,000 inhabitants in Japan.

Mr. QUINDLEN. Yes, sir; that is true.

About 39 percent of the weapons used were used against the industrial and population areas, about 12 percent were used against Atomic

overpressure produces a crushing effect on the structure as it engulfs it. Since the blast wave is also a mass of air in motion at very high velocity, it exerts a dynamic force on the structure, tending to translate it in much the same manner as a hurricane wind. Such structures as multistory brick apartment houses are quite vulnerable to the blast wave. (See fig. 4.) All such structures would be destroyed, collapsed, within a radius of 7 miles from ground zero for a 10-MT weapon; that is, one having a total energy equivalent of 10 million tons of TNT.

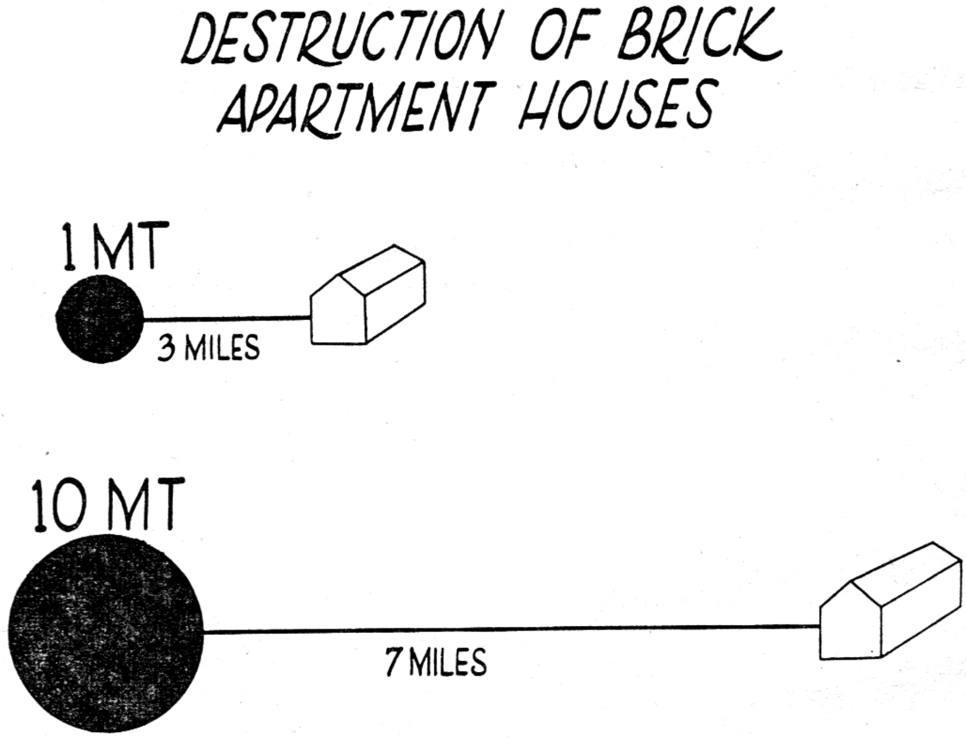
If we decrease the yield by a factor of 10, we have a 1-megaton weapon. For this yield, all such structures within a radius of over 3 miles from ground zero would be destroyed for a surface burst. Thus, a factor of 10 in yield will change the radius of blast damage by a factor of little more than 2.

Senator HICKENLOOPER. Just a moment, Mr. Chairman.

Representative HOLIFIELD. Senator Hickenlooper.

Senator HICKENLOOPER. I am having a little trouble here with the verbiage. You say if we decreased the yield by a factor of 10, we have a 1-megaton weapon. Then this sentence——

FIGURE 4



Dr. SHELTON. It refers to the previous sentence. We decrease the 10 megatons to 1 megaton.

Senator HICKENLOOPER. I understand you decrease the 10 to 1, but then this sentence.

For this yield, all such structures within a radius of over 3 miles from ground zero would be destroyed for a surface burst.

As I take it that statement says everything over 3 miles beyond the center of the surface burst would be destroyed whether it was a hundred miles away or 200 miles away.

Dr. SHELTON. I can understand the problem there.

Senator HICKENLOOPER. We are dealing with a very technical and with a very, if I may use the word, frightening subject here, and I am concerned with the literal statements that are made.

sive window damage at 25 miles from a 1-megaton burst, and it would be an extreme hazard out to about 7 miles. Don't stand behind windows in an attack. First you will get burned and then you will have fine glass splinters driven into you very deeply within distances like 7 miles from a 1-megaton burst.

Representative HOLIFIELD. Every schoolroom in the United States has tremendous expanses of glass.

Dr. SHELTON. Yes, sir.

Representative HOLIFIELD. I think this is a very important point you are bringing up, and I am sure it will be gone into in more detail when the blast witness appears before us.

Dr. SHELTON. Yes. Glass in any disaster like the Texas City disaster is one of the primary materials found in the normal home which can result in blinding and all other types of effects due to the flying small splinters of glass.

My long acquaintance and friend, Dr. White, will fully expound on the hazard of debris, and particularly flying glass.

IV. SUMMARY OF EFFECTS FOR NUCLEAR WEAPONS FOR 1 AND 10 MEGATONS

To summarize the effects of nuclear weapons, they are blast, which is primarily a damaging agent to inanimate objects such as buildings, and it does produce flying debris which is a hazard to man.

The cratering effect results in the destruction of even deep underground structures. Thermal radiation damages both humans and combustible structures and materials. Nuclear radiation, including both the initial and the local residual fallout are primarily hazards to man and animals and can deny man the use of inaminate objects. For reference, I have included in table 1 the effects that I have been discussing for the last hour or so.

TABLE I.—*Summary of effects of the assumed nuclear weapons 1 to 10 megatons*

	1 megaton	10 megatons
A. Inanimate objects:		
1. Crater (dry soil)	Radius, 650 feet Depth, 140 feet	Radius, 1,250 feet. Depth, 240 feet.
2. Brick apartment houses collapse	Radius, 3 miles	Radius, 7 miles.
3. Ignition of light kindling materials	Radius, 9 miles	Radius, 25 miles.
B. Man:		
1. Blast injury (flying debris)	Radius, 3 miles Area, 28 square miles	Radius, 7 miles. Area, 150 square miles.
2. 2d degree burns on bare skin	Radius, 9 miles Area, 250 square miles	Radius, 25 miles. Area, 2,000 square miles.
3. Initial nuclear radiation (700 r.e.m.).	Radius, 1.5 miles Area, 7 square miles	Radius, 2 miles. Area, 12.5 square miles.
4. Fallout, 15-knot winds (450 r.e.m. in 48 hours, no shielding).	40 miles downwind, 5 miles crosswind. Area, 200 square miles	150 miles downwind, 25 miles crosswind. Area, 2,500 square miles.

Moving to man, let us just repeat again, blast injury, due to flying debris, occurs out to about 3 miles for a megaton weapon, and about 7 miles for a 10-megaton weapon. The areas there are about 28 square miles and 150 respectively. The burn area is a very large area, as you see, for a 10-megaton burst, about 2,000 square miles on clear days, or when the bomb thermal is easily seen. Fallout; in this case

450 rem in 48 hours, and no shielding, occurs in an area of about 2,500-square miles for a 10-megaton weapon.

Running down the columns, you notice that 10 megatons is 10 times the energy release of 1 megaton. But notice that the effects only reach out sometimes a factor of two, sometimes a factor of three, seldom ever a factor of four for the larger yield burst. A 10-megaton yield does not reach out to 10 times the distance. The distances are rather slow functions of yield, usually a factor of two, sometimes a factor of three. This is the variation in distance of a given effect from 1 to 10 megatons.

I did not feel that in the testimony I should cover two, three, and eight megatons. They can be interpolated in between the distances given and the uncertainties of effects are probably larger than warranted by exact mathematics for the other yields.

Representative HOLIFIELD. It occurs to me, Dr. Shelton, in the responses to Mr. Hosmer's questions, and other questions from members that you might want to prepare a statement in regard to this rate dose. You might include in that the factors of difference between, let us say, 10, 100-kiloton weapons, and 1 megaton weapon and such other pertinent information as you think would clear up and remaining doubts. We realize that we cannot cover the whole field, but we will try to do the best we can.

Dr. SHELTON. I will certainly do that, sir. (See table I, p. 41.)

Representative HOLIFIELD. Are there any questions of Dr. Shelton? If not, there is one question I would like to ask you, Doctor. Is it not true that if human beings are in the blast area, it is not only the external pressure upon the human individual's body which is dangerous, but also the human being himself becomes a flying missile, and is propelled through the air until he does strike an inanimate structure?

Dr. SHELTON. That is precisely right, sir. The body is able to withstand overpressures quite well. It is the flying debris, the translation of the man himself in the hurricane-like winds that accompany the bomb. It is this sort of thing that always accompanies the blast and produces the blast casualties.

Representative HOLIFIELD. Did you have anything else to add?

Dr. SHELTON. No, sir.

Representative HOLIFIELD. Thank you very much, Dr. Shelton. It might be well for the record to show that Dr. Shelton is Technical Director of the Defense Atomic Support Agency. He has been active in the atomic energy field since 1952. During the spring of 1955 he served as technical adviser to the military effects test group at Operation Teapot, and in 1953 participated in Upshot-Knothole. He has also participated in Operation Redwing in 1956, Operation Plumbbob in 1957, and Operation Hardtack in 1958. Dr. Shelton was born in 1924. He received his bachelor of science, master's, and doctor of philosophy, all in physics from the California Institute of Technology, and prior to joining the Defense Atomic Support Agency (formerly the Armed Forces Special Weapons Project), Dr. Shelton was with the Sandia Corp. in the weapons effects field.

tion. This is one meteorological condition, and one attack pattern.

Shall I proceed?

Representative HOLIFIELD. Proceed, Mr. Shafer.

Representative WESTLAND. May I ask one further question?

Representative HOLIFIELD. Mr. Westland.

Representative WESTLAND. How did you happen to choose the setup that you did?

Mr. SHAFER. This attack pattern, sir.

Representative WESTLAND. Yes.

Mr. SHAFER. It was provided by the committee.

Representative HOLIFIELD. The attack pattern, as shown in the handouts, was established as a reasonable type of attack after a great deal of consultation on the part of the members of the subcommittee and the staff with people who are experts in the field. This study, for instance, is approximately 1,500 megatons on the United States whereas I believe a previous study by the Civil Defense Administration went as high as 2,500.

Is that not true, Mr. Shafer?

Mr. SHAFER. We have studied attacks of this size and other sizes, sir.

Representative HOLIFIELD. Can you give at this time the different operation alerts and the amounts used in those attacks from memory?

Mr. SHAFER. Not very well from memory. I believe Opal 57 was about 384 megatons, and Opals 58 and 59 about 675 megatons.

Representative HOLIFIELD. There was one at 2,500.

Mr. SHAFER. This was not an operation alert. This was a special internal exercise which we called Sentinel.

Representative HOLIFIELD. Was the 2,500 study effects made public?

Mr. SHAFER. Yes, to this particular committee in 1957, sir.

Shall I proceed, sir?

Representative HOLIFIELD. Yes.

Mr. SHAFER. This table shows the effects of the attack on dwellings within the United States. It indicates the numbers of units receiving severe, moderate, and light blast damage. Further, it shows the total units outside the blast areas which would be under fallout intensities exceeding 3,000 roentgen-hours; 1,000 to 3,000 roentgen-hours; 100 to 1,000 roentgen-hours and less than 100 roentgen-hours when normalized to H+1 hour.

Effects on dwelling

	Units
Blast effects:	
Severe damage	11, 800, 000
Moderate damage	8, 100, 000
Light damage	1, 500, 000
Fallout effects:	
Greater than:	
3,000 r/hr	500, 000
1,000–3,000 r/hr	2, 100, 000
100–1,000 r/hr	10, 400, 000
Less than: 100 r/hr	11, 700, 000

It should be noted that 11.8 million dwellings would suffer severe damage—to the extent that they would not be salvageable. This is approximately one-fourth of the dwellings in the United States. And an additional 8.1 million dwellings or about 17 percent of the national

total would suffer moderate damage and would have to be vacated for major repairs. Further, 1.5 million dwellings or about 3 percent would suffer light damage and could be repaired without being vacated. This totals 21.4 million dwellings damaged.

Representative HOLIFIELD. How does that rate relate to the total number of dwellings?

Mr. SHAFER. This is a little less than half, sir.

Representative HOSMER. Give us the number.

Mr. SHAFER. 46.1 million dwellings total in the United States and this is 21.4 million dwellings damaged, a little less than 50 percent. Let us say 45 percent.

Approximately 500,000 dwellings, outside the areas of blast damage, would be affected by fallout intensities exceeding 3,000 r/hr. normalized to H+1 hour. These are the red shaded zones on the fallout maps. The homes in these zones would have to be evacuated and abandoned for probably a year, perhaps longer.

About 2.1 million dwellings, outside the areas of blast damage, had fallout intensities varying between 1,000 and 3,000 r/hr. when normalized to H±1 hour. These are the blue shaded areas on the fallout maps. The homes in these zones would have to be evacuated and abandoned for a period for several months to perhaps a year in some instances. Actually, the period of abandonment would depend upon this effectiveness of decontamination and the rapidity of radiological decay. However, this subject is scheduled for discussion later by another group.

Approximately 10.4 million dwellings, outside the areas of blast damage, had fallout intensities varying between 100 and 1,000 hr. when normalized to H+1 hour. These are the yellow shaded zones on the fallout maps. If major decontamination efforts were undertaken most of the homes in these yellow areas could be made available for living by 60 days' postattack.

STATEMENT OF DR. TERRY TRIFFET,[1] U.S. NAVAL RADIOLOGICAL DEFENSE LABORATORY, HUNTERS POINT, CALIF.

Dr. TRIFFET. Mr. Chairman, gentlemen of the committee, I have prepared a formal statement which I would like to submit for the record.

Representative HOLIFIELD. It will be received.

(The statement referred to follows:)

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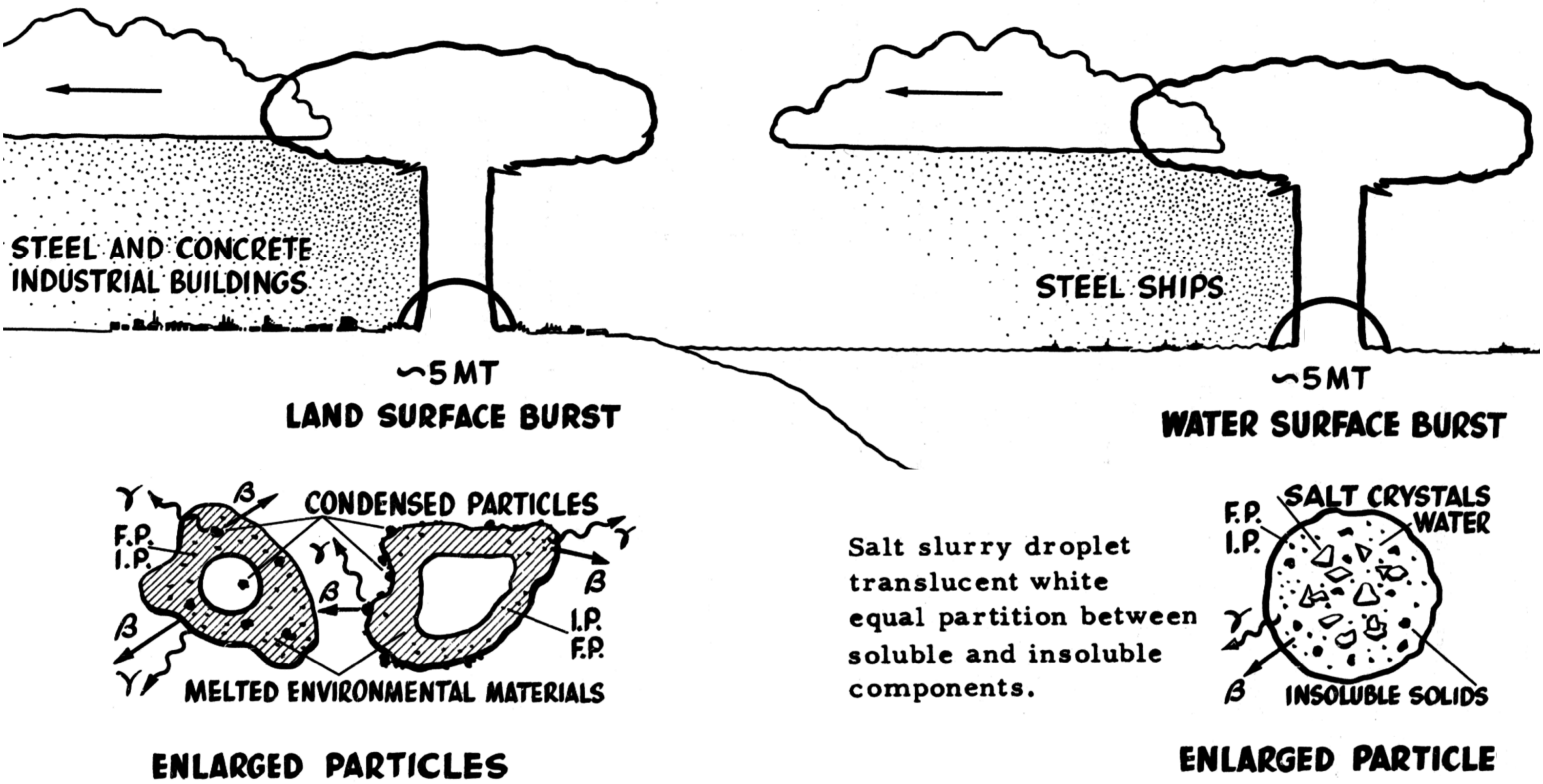
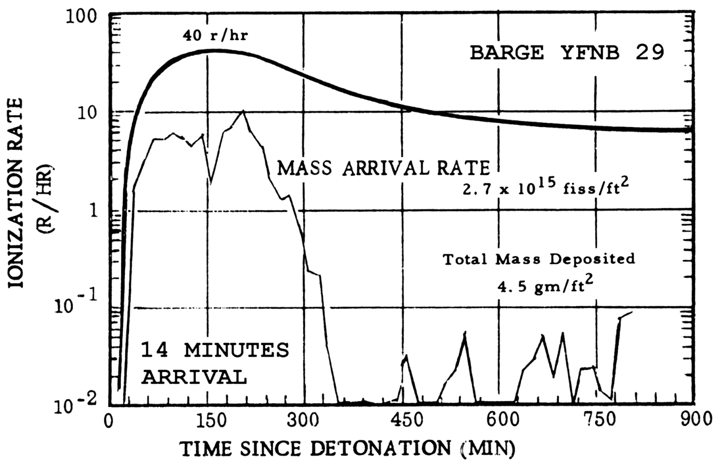
[1] Profession: Research engineer. Date and place of birth: June 10, 1922, Enid, Okla. Parents: R. B. Triffet, Enid, Okla. Married: Millicent McMaster, May 26, 1946. Children: Patricia A. Triffet. Education: B.A. (with honors) Human., University of Oklahoma, 1945; B.S. (with special honors) engineering, University of Colorado, 1948; M.S., engineering, University of Colorado, 1950; Ph. D., engineering, Stanford University, 1957. Professional and honorary societies: APS, ASCE, Society of Rheology, AAAS, Sigma Xi, Phi Beta Kappa, Tau Beta Pi. Work history: 1947–50, instructor, College of Engineering, University of Colorado; 1950–55, rocket research and development, U.S. Naval Ordnance Test Station, China Lake, Calif.; 1955 to present, Head, Radiological Effects Branch, U.S. Naval Radiological Defense Laboratory, San Francisco, Calif. Publications: Several papers and technical reports on effects of radiations on materials, properties of fallout, and radiological effects. Present residence: Palo Alto, Calif.



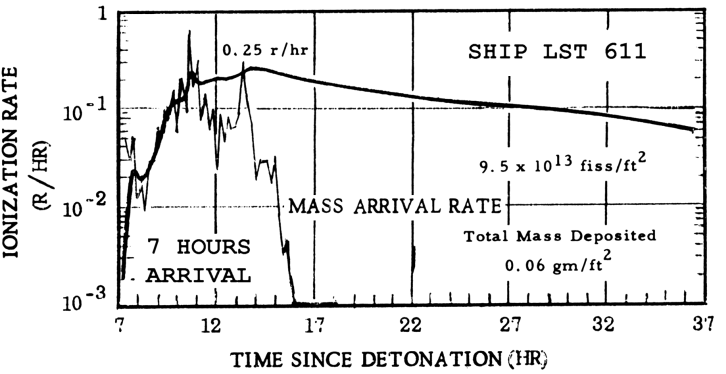
Triffet, T. and LaRiviere, P. D.; Characterization of Fallout, Volume I; Operation REDWING, Project 2.63, Final Report, August 1958

ARRIVAL CHARACTERISTICS OF LAND SURFACE BURST FALLOUT

5 MT TEWA (87% FISSION), 7.84 STAT. MILES WSW

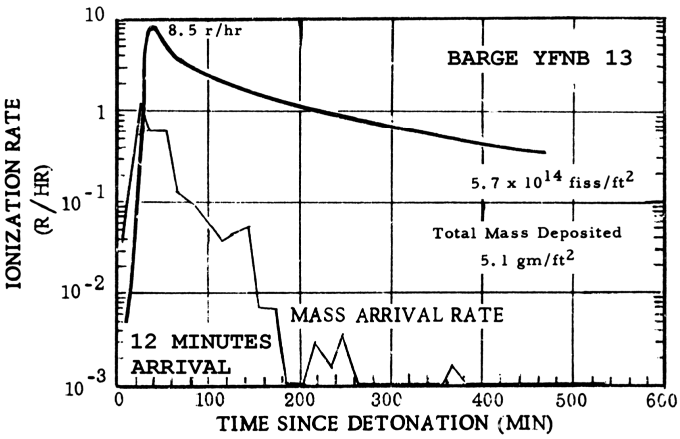


5 MT TEWA (87% FISSION), 59.3 STAT. MILES NW

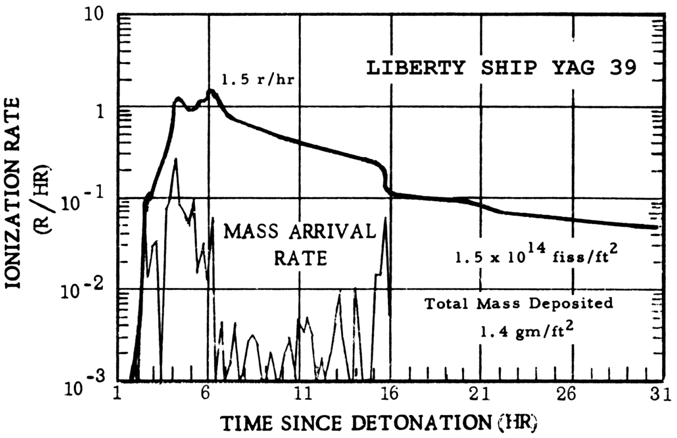


ARRIVAL CHARACTERISTICS OF WATER SURFACE BURST FALLOUT

4.5 MT NAVAJO (5% FISSION), 7.54 STAT. MILES W



4.5 MT NAVAJO (5% FISSION), 21.0 STAT. MILES N



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RADIATION CHARACTERISTICS OF LAND SURFACE BURST FALLOUT

Average γ Energy	8 mi downwind	60 mi downwind
1 hr	--	1.0 mev
2 hr	--	0.95
1/2 day	--	0.60
1 day	--	0.40
1 week	0.25 mev	0.35
1 mo	0.45	0.65

RADIATION CHARACTERISTICS OF WATER SURFACE BURST FALLOUT

Average γ Energy	7 mi downwind	22 mi downwind
1 hr		1.0 mev
2 hr		0.95
1/2 day		0.60
1 day		0.40
1 week		0.35
1 mo		0.65

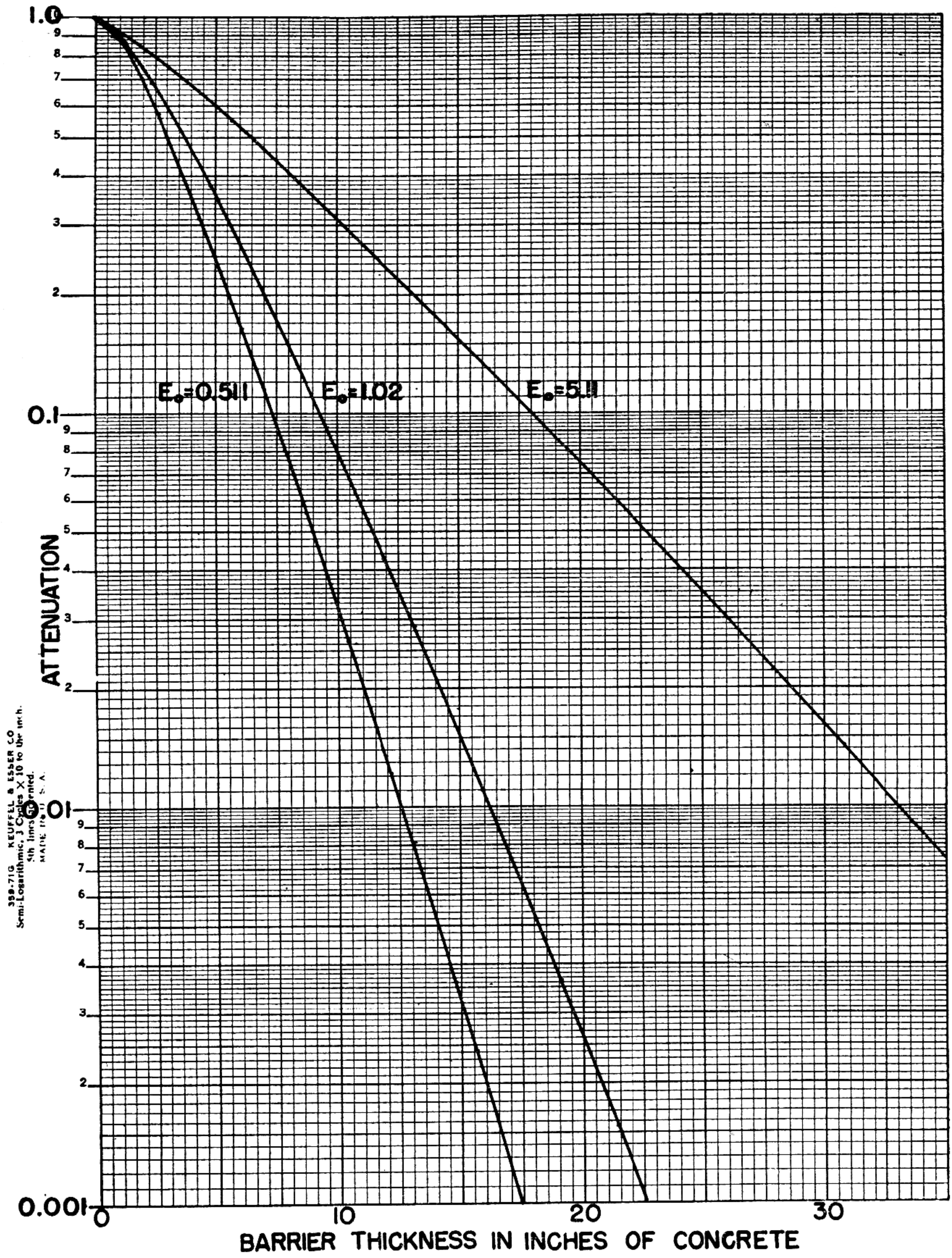

FIGURE 4.—Attenuation of gamma radiation dose as a function of concrete barrier thickness for three different gamma ray source energies. The units of E_o are Mev. The curves were calculated for gamma radiation perpendicularly incident on the barrier

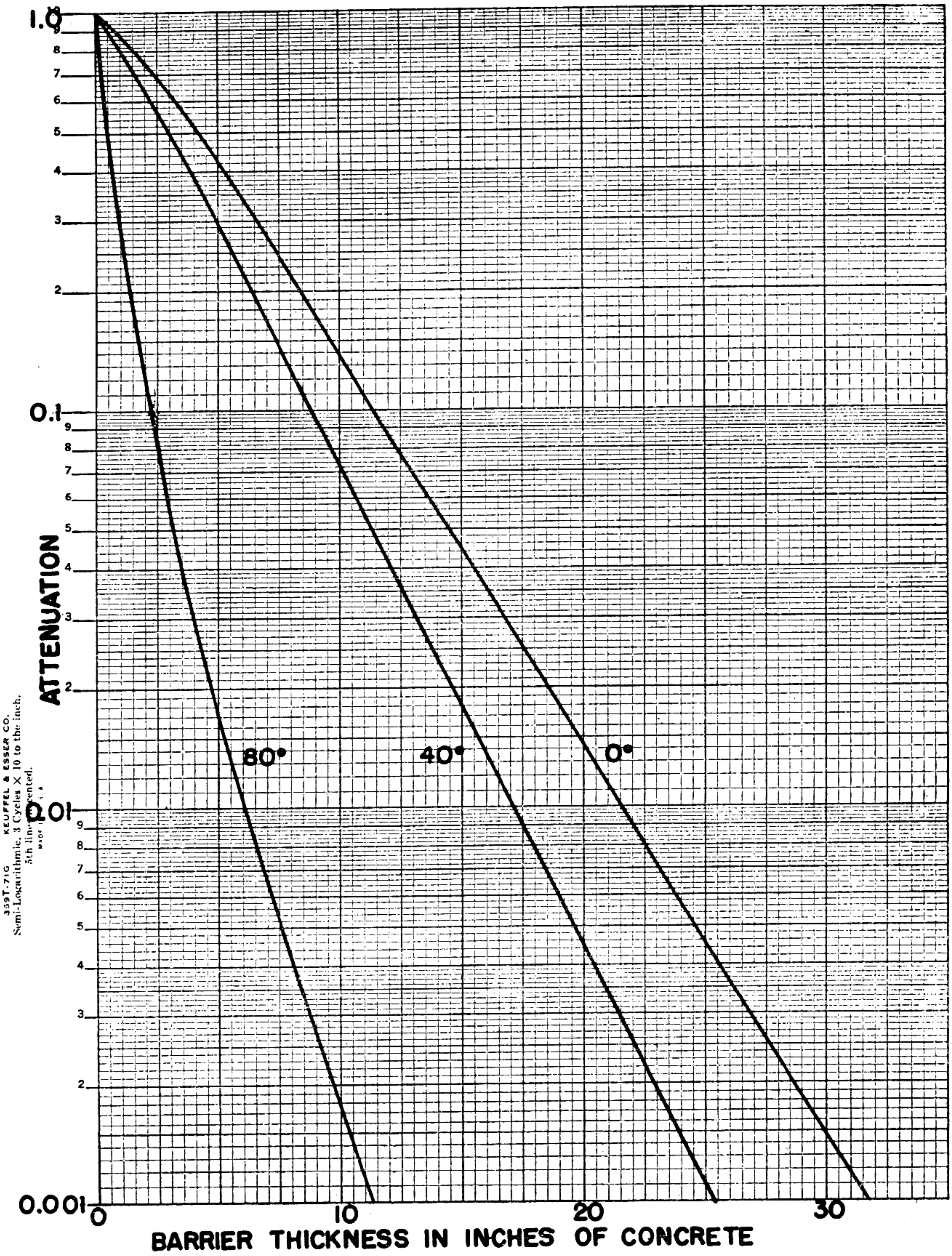

FIGURE 5.—Attenuation of gamma radiation dose as a function of concrete barrier thickness for three different angles of incidence. The curves were calculated for the energy distribution of fission product gamma rays at 1 hour after weapon burst.

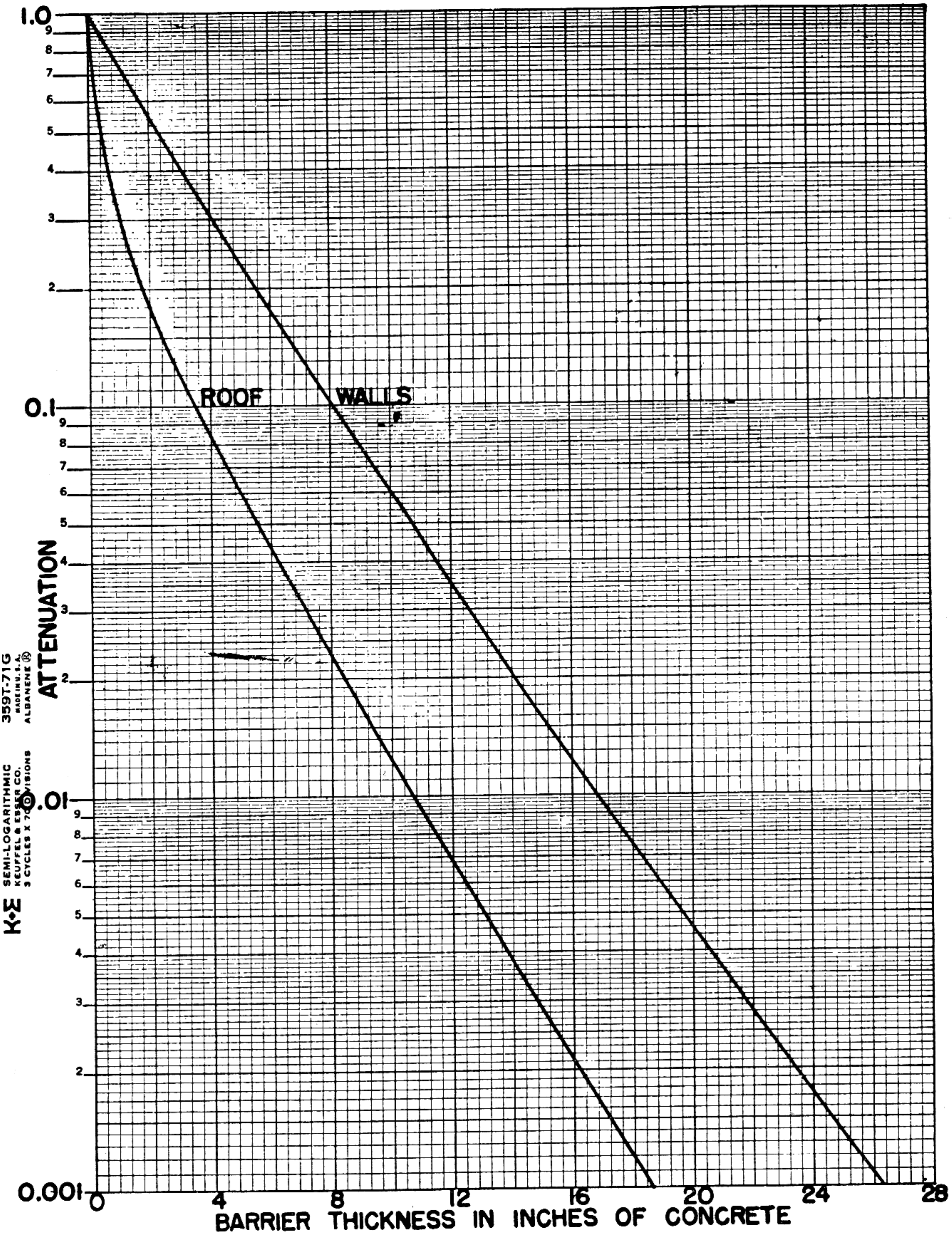

FIGURE 6.—Attenuation of gamma radiation dose as a function of concrete barrier thickness. The curve labeled "roof" gives attenuation of radiation from roof sources as it penetrates the roof and floors. The curve labeled "walls" gives the attenuation of radiation from ground sources as it penetrates the walls. Both curves were calculated for the energy distribution of fission product gamma rays at 1 hour after weapon burst.

III. NATIONAL ACADEMY OF SCIENCES ADVISORY COMMITTEE ON CIVIL DEFENSE, SUBCOMMITTEE ON RADIATION SHIELDING

In the problem of shielding from fallout radiation, as well as in all scientific work, it is important that the theoretical and the experimental work be closely coordinated. With this in mind, the Advisory Committee on Civil Defense of the National Academy of Sciences formed a Subcommittee on Radiation Shielding. This subcommittee is composed of people who are actively engaged in either calculations or experiments. It includes representatives from the Office of Civil and Defense Mobilization, the National Bureau of Standards, Oak Ridge National Laboratory, the Defense Atomic Support Agency, the Naval Radiological Defense Laboratory, Technical Operations, Inc., and the University of California. It was formed last October and has met approximately once every 3 months. This subcommittee also serves in an advisory capacity to OCDM in directing its research efforts on radiation shielding.

TABLE 1.—*Categorization of shelter areas*

Category	Protection factor	Typical examples
A	1,000 or greater	1. OCDM underground shelters. 2. Subbasements of multistory buildings. 3. Underground installations (mines, tunnels, etc.).
B	250 to 1,000	1. OCDM basement fallout shelters (heavy masonry residences). 2. Basements (without exposed walls) of multistory buildings.
C	50 to 250	1. OCDM basement fallout shelters (frame and brick veneer residences). 2. Central areas of basements (with partially exposed walls) of multistory buildings. 3. Central areas of floors near midheight of large multistory buildings with heavy exterior walls and floors.
D	10 to 50	1. Basements (without exposed walls) of small 1- or 2-story buildings. 2. Central areas of floors near midheight of large multistory buildings with light exterior walls and floors.
E	2 to 10	1. Basements (partially exposed) of small 1- or 2-story buildings. 2. Central areas of lower floors in large multistory buildings. 3. Central areas on ground floor in 1- or 2-story buildings with heavy masonry walls.
F	1½ to 2	1. Aboveground areas of low buildings, in general, including residences stores, factories, etc.

TABLE 2.—*Shielding factors in some typical light residential structures* [1]

[Values deduced from experiment]

Structure	Location	Reduction factors [2]			Protection factor [3]
		Roof contribution	Ground contribution	Total	
2 story wood frame house	2d floor center	0.076	0.50	0.58	1.7
	1st floor center	.034	.57	.60	1.7
	Basement center	.015	.028	.043	[4] 23
1 story wood rambler	1st floor center	.10	.54	.64	1.6
2 story brick veneer house	do	.034	.14	.17	[5] 6
	Basement center	.015	.021	.036	[4] 28

[1] Values in this table are from an NBS report, to be published. (Ref. 17.)
[2] Reduction factor is defined as dose rate at the specified location divided by the dose rate outside at 3 feet above the ground.
[3] Protection factor is defined as dose rate at 3 feet above the ground, outside, divided by the dose rate at the specified location.
[4] This factor applies to basements with no exposed walls.
[5] This factor applies only for detector locations below window sill level

MYRON HAWKINS:

the induced radiation in uranium 238. We can refer to a British report which indicates that around 60 percent of the total activity at 4 days—activity in this case is the number of disintegrations—is due to the uranium 239 and neptunium 239 that are produced, as the British say, in either large or small weapons. I believe part of the hump on the curves in the early times, say around 4 days, is largely due to this.

Dr. TRIFFET. Yes. I thought this might be an appropriate place to comment on the variation of the average energy. It is clear when you think of shielding, because the effectiveness of shielding depends directly on the average energy radiation from the deposited material. As I mentioned, Dr. Cook at our laboratory has done quite a bit of work on this. What it amounts to is that at one hour the average energy is about one Mev. This appears, by the way, in the tables that are in my written statement but that I did not present orally.

Representative HOLIFIELD. Mev. means?

Dr. TRIFFET. Million electron volts. At 2 hours it drops to 0.95. At a half day, to 0.6. At 1 week it drops to 0.35. Then it begins to go up again. At 1 month, it is 0.65, 2 months 0.65. The meaning of this is simply that there is a period around 1 week when if induced products are important in the bomb, there are a lot of radiations emanating from these, but the energy is low so it operates to reduce the average energy in this period and shielding is immensely more effective.

Strontium 90, for example, has 33-second krypton as its birth predecessor; cesium 137 derives from a fission chain headed up by 22-second iodine, followed by 3.9-minute xenon. Because of their volatile or gaseous ancestry in the fireball or bomb cloud a number of the high-yield fission products are formed in finely divided particles. Some of these are so small that they are not subject to gravitational settling, and in fact they remain suspended in the earth's atmosphere for many years, providing[6] that they reach the stratosphere at the proper latitude. In any event such fission products would be depleted in the local fallout.

For example, the irradiation of uranium^{238} with low Mev. neutrons forms neptunium 239, a 2.3-day radioelement which W. J. Heiman[7] estimates might constitute 50 percent of the residual activity a few days after a bomb detonation.

At higher neutron energies, such as certain types of thermonuclear weapons produce, natural uranium undergoes an (n,2n) reaction which competes with fast fission in U^{238}. The data of R. J. Howerton[8] show that U^{238} has a fission cross section of 0.6 barn from 2 to 6 Mev., thereafter climbing to a plateau value of 1 barn for neutrons up to 14 Mev. At 6.6 Mev. there is a threshold for the (n,2n) reaction and the reaction has a cross section of 1.4 barns in the range of 10 Mev. The ready identification of U^{237} in fallout points to fast fission of U^{238} as a main energy source in high-yield megaton-class weapons.

[6] See E. A. Martell, "Atmospheric Circulation and Deposition of Strontium 90 Debris," Air Force Cambridge Research Center paper (July 1958). See also W. F. Libby, "Radioactive Fallout," speech of Mar. 13, 1959.

[7] Variation of Gamma Radiation Rates for Different Elements Following an Underwater Nuclear Detonation," J. Colloid. Science, 13 (1958), p. 329.

[8] "Reaction Cross Sections of U^{238} in the Low Mev. Range," UCRL 5323 (Aug. 15, 1958).

RADIOACTIVE FALLOUT AND ITS EFFECTS ON MAN pages 1689-1691

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ATOMIC ENERGY RESEARCH ESTABLISHMENT

The Radiological Dose to Persons in the U. K. Due to Debris From Nuclear Test Explosions Prior to January 1956

By N. G. Stewart, R. N. Crooks, and Miss E. M. R. Fisher

Activity from Neutron Capture

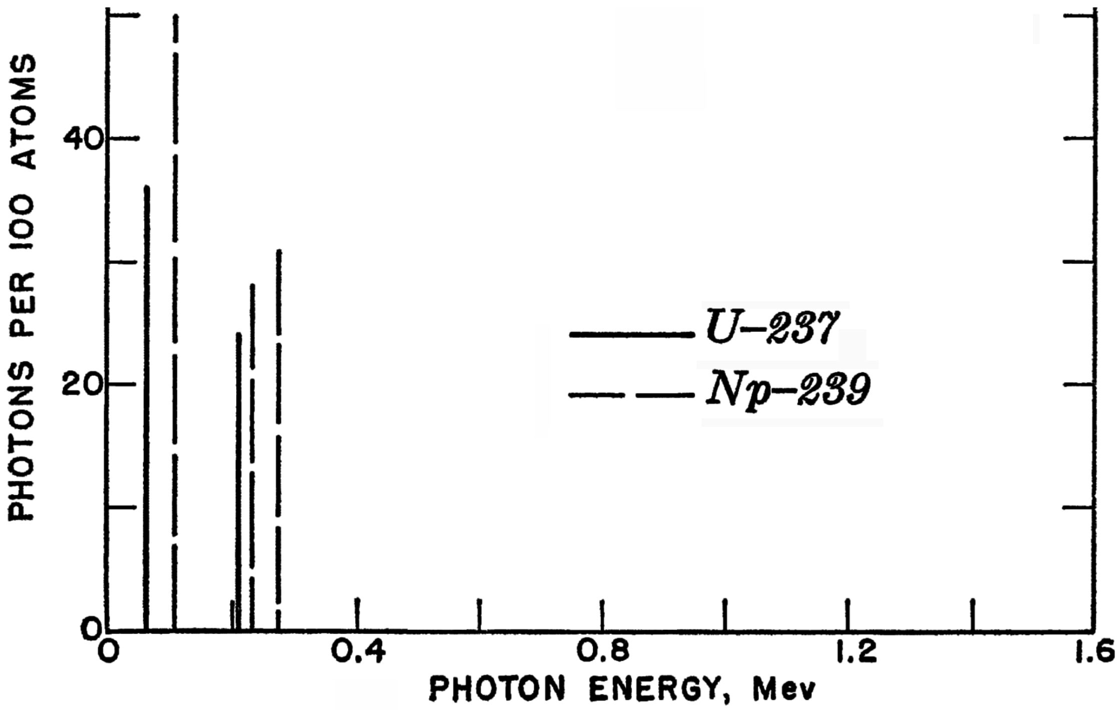
Although several different radioactive elements may be created by the capture of neutrons in materials close to the reacting core of a weapon, the only significant reactions to produce gamma-ray emitters are those associated with the natural uranium which may be used as the tamper material of the bomb.

neutron (low energy) + U-238 ⟶ U-239 ⟶ Np-239

Chemical analysis of the debris shows that in general about one neutron is captured in this way for every fission that occurs, both in nominal bombs and in thermonuclear explosions. The U^{239} decays completely before reaching the U.K. but at four days after time of burst the Np^{239} disintegration rate reaches a peak relative to that of the fission products and accounts for about 60% of the observed activity at that time.

In addition to this, a smaller number of the neutrons in a thermonuclear explosion undergo an (n,2n) reaction with U^{238} to form 6.7 day U^{237} which is also a (β, γ) emitter.

neutron (high energy) + U-238 ⟶ 2 neutrons + U-237



DR HAM:

high-yield nuclear detonation. Rabbits were placed at distances up to 300 nautical miles from the point of detonation in order to obtain the necessary data.

The biomedical project showed that a very high altitude nuclear explosion can be particularly damaging to the eye because of the rapid rate at which the power pulse delivers thermal energy and the relatively low atmosphere attenuation encountered. A high-altitude detonation in the megaton yield range, such as Teak, delivers a great percentage of its thermal energy during a small fraction of a second after the detonation. Consequently, with a blink-reflex time of just over a quarter of a second for the rabbit and less than a quarter of a second for man, nearly all of the radiant exposure from a very high-altitude burst is received by the retina before the eye can be protected by blinking if the person is looking directly at the burst at the time of detonation. This is in contrast to low altitude detonations of the same size, where the power pulse is much slower in overall delivery of its thermal component and where the blink reflex can provide a measure of protection. TEAK, 3.8 Mt @ 77km!

Small retinal burns were produced in the rabbits at distances up to 300 nautical miles. Burn diameters consistently correlated with distance from the burst, with progressively smaller lesions being encountered at increased distances. For example, the burn lesions were approximately 2 millimeters in diameter at about 40 miles distance, decreasing to 0.5 millimeter at 300 miles. Corresponding lesions of smaller diameter might be expected at larger distances provided the burst height were great enough to allow a direct view of the fireball over the edge of the horizon. Curvature of the earth will cause the position of the fireball to be below the horizon, and therefore incapable of inflicting retinal damage.

In order to preclude damage to the sooty tern, a large bird indigenous to the Johnston Islands, special precautions were taken during the Orange shot. A water spray simulated rain and kept the birds grounded. Smoke together with local clouds further attenuated thermal effects.

No precautions were necessary for the Teak shot due to its higher altitude. The protective measures for the Orange shot were successful.

SUMMARY OF TEST OBJECTIVES AND RESULTS REGARDING FLASH BLINDNESS AND RETINAL BURNS

The effect of nuclear detonations on human eyes was recognized early in the testing procedures when the Aviation School of Medicine of the U.S. Air Force performed Project 4.3, "Flash Blindness," in Operation Buster. The objective of this project was to evaluate the visual handicap which might be expected in military personnel exposed, during daylight operations, to the flash of an atomic detonation and to evaluate devices developed for the purpose of protecting the eyes against visual impairment resulting from excessive exposure to light. The data obtained on this test, as revealed in the test report, showed that no serious handicap is encountered during exposure to atomic detonation during daylight operations at the distance from the detonation which would be safe from the standpoint of other hazards. This conclusion was subsequently disproved by the recent Hardtack test series in the Pacific, using rabbits as specimens.

In the Tumbler-Snapper test series retinal burns were not investigated, with the Air Force School of Aviation Medicine this time investigating flash blindness. However, on this series some work was done on atmospheric transmissivity, which has proved subsequently to be of some help in the problem of retinal burn prediction.

In Operation Upshot-Knothole, research was conducted to determine to what degree the flash of an atomic detonation impairs the vision and reduces the efficiency of military personnel during nighttime operations. This is a serious problem because the individual has pupils which are more or less widely dilated, depending upon the amount of light to which the eye is being exposed prior to detonation. The conclusion was that a significant loss of central peripheral vision occurs temporarily following exposure to an atomic detonation. It was also concluded that the types of filters tested served to shorten by about 30 percent the normally long period of incapacitation in unprotected individuals as measured in the previous Tumbler-Snapper operations.

Dr. MIXTER. The exact number is presumably incalculable. In any case the number is mentioned only as an indication of the complete hopelessness of the problem confronting the medical profession.

(The following was subsequently handed to the chairman of the subcommittee:)

DEAR MR. HOLIFIELD: There are 226,625 physicians in the United States, of which 16,598 are in Government service, that is, Army, Navy, Air Force, Public Health Service, Veterans' Administration, and Indian Service. Figures are for the year 1958.

FRANK BARTON,
Secretary of the Council on National Defense,
American Medical Association.

Representative HOLIFIELD. Proceed, Dr. Ham.

Dr. HAM. Yes, sir. It is obvious that under such conditions it would be impossible to give burns or any other casualties such treatment as is now known to result in minimal mortality. The surviving doctors' primary responsibility must be to select those casualties reasonably capable of ultimate survival, and to concentrate every effort upon their survival. This means that under conditions of inadequate supplies of opiates, dressings, and sterile fluids, the vast majority of casualties will receive only token treatment. It is not the province of the present discussion to define accurately either the number of casualties or how they will be treated, but it must be unequivocally stated that, under the conditions predicated for this investigation, only a small percentage of the injured population could, or indeed should receive even an approximation to adequate medical treatment.

Burn victims might be sorted into three groups according to percentage burn area, 25 percent or less, 25 to 50 percent, and greater than 50 percent. Those having burns covering 50 percent of the body area or more would be given opiates for pain and neglected; the group having 25 to 50 percent area burns would be treated with all available resources in the field; the 25 percent or less groups would be given oral electrolyte treatment, opiates for pain, and dismissed.

Representative HOLIFIELD. Would you please tell me what oral electrolyte treatment is?

Dr. HAM. Dr. Mixter will.

Dr. MIXTER. This very simply means salt water mixed in a proportion which will not make the person ill but will supply them with the salt, and if you have the soda bicarb, which is the ideal fluid, to allow their life to be prolonged. Extensively burned people are not capable of eating any solid food. They won't accept it. Various emergency fluids have been worked out. This information should be a part of the information of any one concerned with any type of disaster work. It should be known because the fluids used for intravenous use will be in short supply, indeed if there are any. Even pure water suitable for drinking will be in short supply. Oral electrolyte is salt water.

Representative HOLIFIELD. That is very plain. Even I understand that.

Dr. HAM. Burns involving more than 25 percent of the total body area represent severe traumatic cases demanding at least five details of emergency treatment: (1) relief of pain; (2) emergency dressing, if possible; (3) prevention and treatment of burn shock; (4) salt and

water requirements to insure adequate urinary output; (5) the most feasible antibiotic therapy to aid in combating infection. Of all the types of traumatic injury following a nuclear attack, severe burns make perhaps the greatest demands upon medical personnel and resources. Successful treatment requires stockpiles of plasma, whole blood, plasma substitutes, antibiotics, emergency dressings, narcotics, et cetera. The treatment period is long and arduous. Burn wounds greater than first degree always become infected and prolong the treatment phase. Exposure to ionizing radiation complicates the picture because the body's defenses against infection and bleeding have been impaired. Combined injury from thermal and ionizing radiation presents grave problems in therapy. ⇒ DUCK AND COVER.

The conclusion seems inevitable that millions of severe burn casualties would overwhelm our capacity for adequate medical treatment. Mortality figures for burn victims would be extremely high. It is no exaggeration to say that, after nuclear attack, burn casualties represent the most serious immediate medical problems facing the Nation.

Representative HOLIFIELD. Thank you very much, Dr. Ham.

Are there any questions of the witness?

Representative WESTLAND. Mr. Chairman.

REPRESENTATIVE HOLIFIELD. Mr. Westland.

Representative WESTLAND. The nations have been using fire as a weapon for hundreds of years, all the way from the Indians using bow and arrows with fire on them to set the house on fire, up to recent wars with flamethrowers, napalm bombs, and so forth. Isn't what you are really saying here is that man has now created a weapon with which he can destroy his fellow man in greater quantities and with greater efficiency? Is that not just about the size of it?

Dr. HAM. Yes, sir; I think that is, with very great efficiency, especially in terms of magnitude of something that we have never had previous experience in. In modern warfare in the past there have been filled hospitals and bad burns have been able to be treated because they came in in small numbers. But you are here faced with the instant production, so to speak, of perhaps millions of burns casualties, and the question is what can we do about it. The answer we are trying to drive across is that the ordinary treatments that we do adopt under the best conditions for burns would be absent and that the mortaility figures for burns would be much greater under such conditions. It is our estimate and feeling that burns would produce a tremendous amount of mortality in the country under nuclear attack.

Representative WESTLAND. You are saying that the medical protection would simply be unable to cope with such a situation.

Dr. HAM. Exactly, sir.

Representative WESTLAND. I would assume that this same information which you have presented here so well this afternoon is available to other nations, too, who possess this lethal weapon.

Dr. HAM. Yes, sir; I think that is correct.

Representative BATES. Doctor, could not a lot of these things which you have suggested here be done by first aid treatment by people who have had a little experience in this field?

Dr. HAM. Yes, I think that is very true. I think Dr. Mixter would prefer to speak to you about that, Mr. Bates.

DR CLAYTON S. WHITE:

Fourthly, from the findings of Ruff (84), it is possible to deduce a velocity of about 8 ft/sec (6 mph) as likely to produce spinal fracture assuming impact with a solid surface in the sitting position.

The above data encourages one to adopt an impact velocity of 10 ft/sec as a tentative threshold criteria for human damage from abrupt decelerative impact following displacement by blast-produced winds. Though arbitrarily chosen, the 10 ft/sec (6.8 mph) figure is quite likely low enough to avoid any significant number of casualties and if serious injuries occur, they are likely to be few indeed.

Empirical work by Taborelli, et al. (51, 52) in the 1957 Nevada Test Series, using 160 lb anthropometric dummies exposed at stations where measured overpressures were 5.3 and 6.9 psi, demonstrated the displacement possible to humans from nuclear blast. Table 10 summarizes the findings.

Table 10

Blast Displacement of 160 Lb Anthropometric Dummies

Max pressure psi	Max Q psi	Initial dummy position	Max horizontal velocity ft/sec	Time to max velocity sec	Displacement in ft
5.3	1.8	Standing	21.4	0.5	21.9 downwind
"IDEAL"		Prone	zero	-	None
6.9	15.4	Standing	not known	not known	256 downwind 44 to right
Smoky, 43 kt		Prone	not known	not known	124 downwind 20 to right

"PRECURSOR" BLAST

Even at 5 psi the maximal velocity attained in 0.5 sec by the dummy was a little over 21.4 ft/sec, which speed is well above those required to fracture the skull and lower extremities. Though the displacement velocity at 6.9 psi was not obtained in the Nevada studies, the total displacement of 124 and 256 ft for the prone and standing dummies, respectively, demonstrates the unequivocal displacement hazard which can occur following nuclear explosions.

Beta Radiation Skin Lesions (Beta Burns) From Fallout Radiations

DR. BOND:

Now with respect to the beta lesions in the Marshallese (the affected areas are termed "beta lesions" since a very large percentage of the dose received by the skin surface resulted from beta radiation). These individuals were showered with radioactive fallout following the detonation in March 1954 of a high yield thermonuclear device during weapons testing at the Pacific Proving Grounds. The wind shifted unpredictably following the detonation, leading to unexpected fallout in significant amounts being deposited on the atolls of Rongelap, Rongerik and Uterik. The 64 Marshallese individuals on Rongelap at the time, 105 nautical miles from the detonation, received the largest exposure and I shall confine my remarks to this group. The fallout was visible on Rongelap, described as snowlike, and began falling approximately 5 hours after the detonation. The material was deposited on the ground and on the thatched-roof houses, as well as on the clothes, hair, and skin of the people. The individuals remained on the island for approximately 2 days, at which time they were transferred to the U.S. Naval Station at Kwajalein for medical observation.

No dosimeters were present on the island, and the doses of gamma radiation received were estimated from average readings of survey instruments held 3 feet above the ground, of the order of a week following the detonation. From these readings it was estimated that the Rongalapese received approximately 175 r. of penetrating gamma radiation, dose measured essentially free in air. In addition to gamma exposure, these individuals received large doses of beta radiation in areas of the body in which the fallout material was adherent to the skin. It is not possible to calculate with any reasonable degree of accuracy the dose to the skin from beta radiation. Estimates involving the known minimal dose of radiation to cause hair loss or epilation indicate that the surface of the skin probably received of the order of 5,000 or more rads.

With regard to symptomatology, with the exception of nausea in some two-thirds of the individuals during the first 2 days, and vomiting and diarrhea in a smaller percentage, no symptoms developed that could be ascribed to penetrating gamma radiations. However, the penetrating radiation did result in marked peripheral blood count changes. No deaths occurred as the result of irradiation and all signs and symptoms except the initial gastrointestinal symptoms referred to were related to beta lesions of the skin. CALCIUM HYDROXIDE FALLOUT

Within the first 2 days of exposure a number experienced transitory itching and burning of the skin, and some complained of lacrymation. No further signs or symptoms referable to the skin were noted until about 2 weeks after exposure, when skin lesions and epilation, or loss of hair, was noted.

It is clear that the great bulk of the beta dose was derived from material deposited on the skin, and the habits of the Marshallese tended to maximize the deposition of the material on the skin. They wore rather scanty clothing and no shoes, and spent a good deal of time out of doors. The use of thick hair oil aided in collecting the material on the head. The high humidity and sweating contributed by encouraging the material to collect on the skin. Thus one might conclude that the beta lesions would constitute an extensive problem only under the rather favorable conditions for it that were present in the Marshallese, and that the problem would essentially not exist should an American city be subjected to fallout radiation.

Clothing protected by NOT RETAINING fallout (not by shielding beta rays!)

Even a thin layer of clothing protected the Marshallese from visible damage from fallout from the particular device employed. I do not know to what degree the beta energy spectrum from this device would represent closely that from more recent devices. One cannot ignore the possibility of fallout coming down in rain, in which event clothing, if not removed, might provide the ideal situation for severe beta lesions.

FIGURE 1

FIGURE 1.—Extensive lesions, 46 days after exposure, on a young boy who wore little clothing at the time of exposure. Note particularly the lesions on the neck, in the armpits and at the beltline—areas where the fallout material tended especially to collect.

FIGURE 2

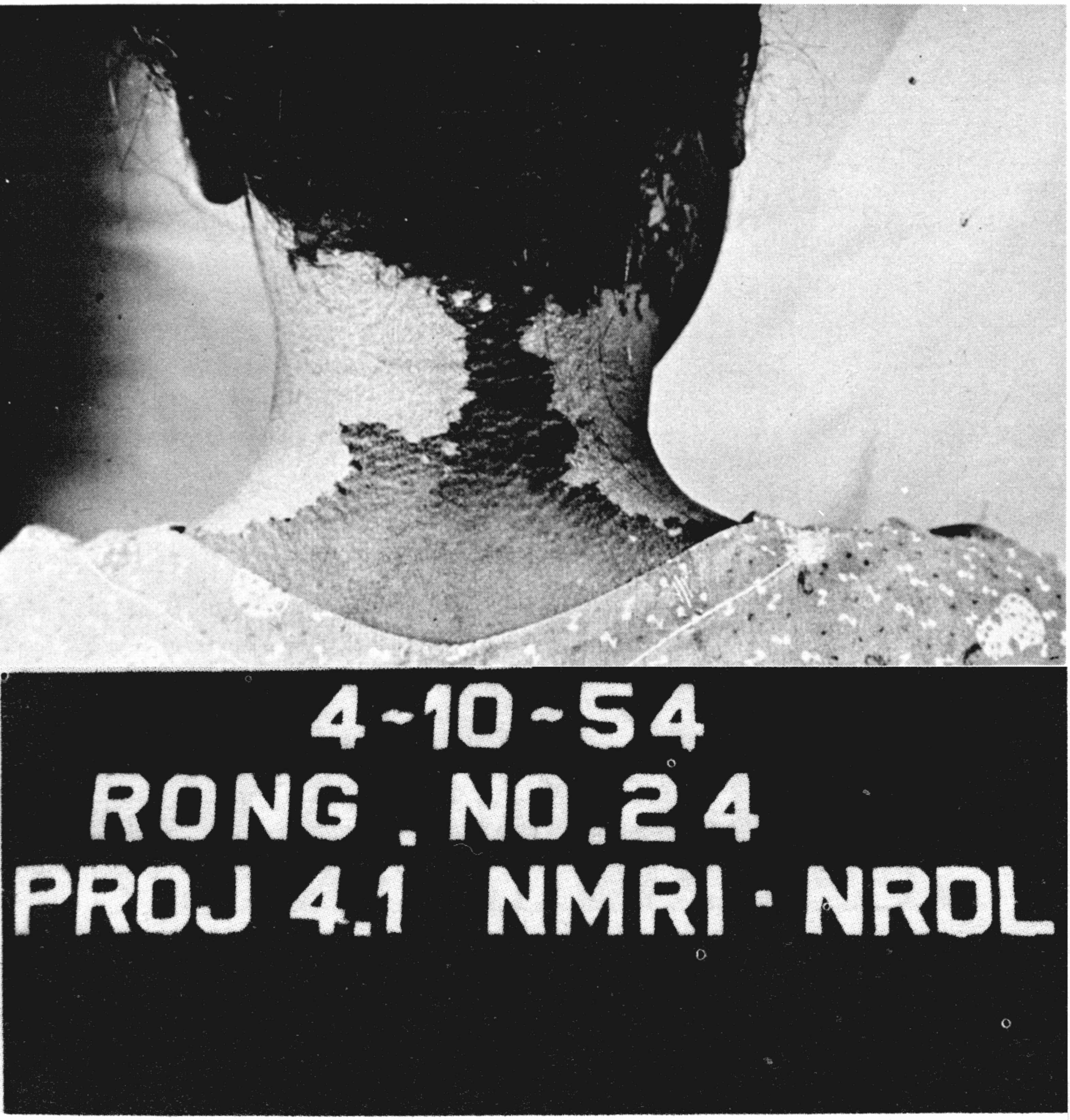


FIGURE 2.—Extensive neck lesions on a woman approximately 30 days after exposure. Note the superficial nature of the lesions, resembling severe sunburn.

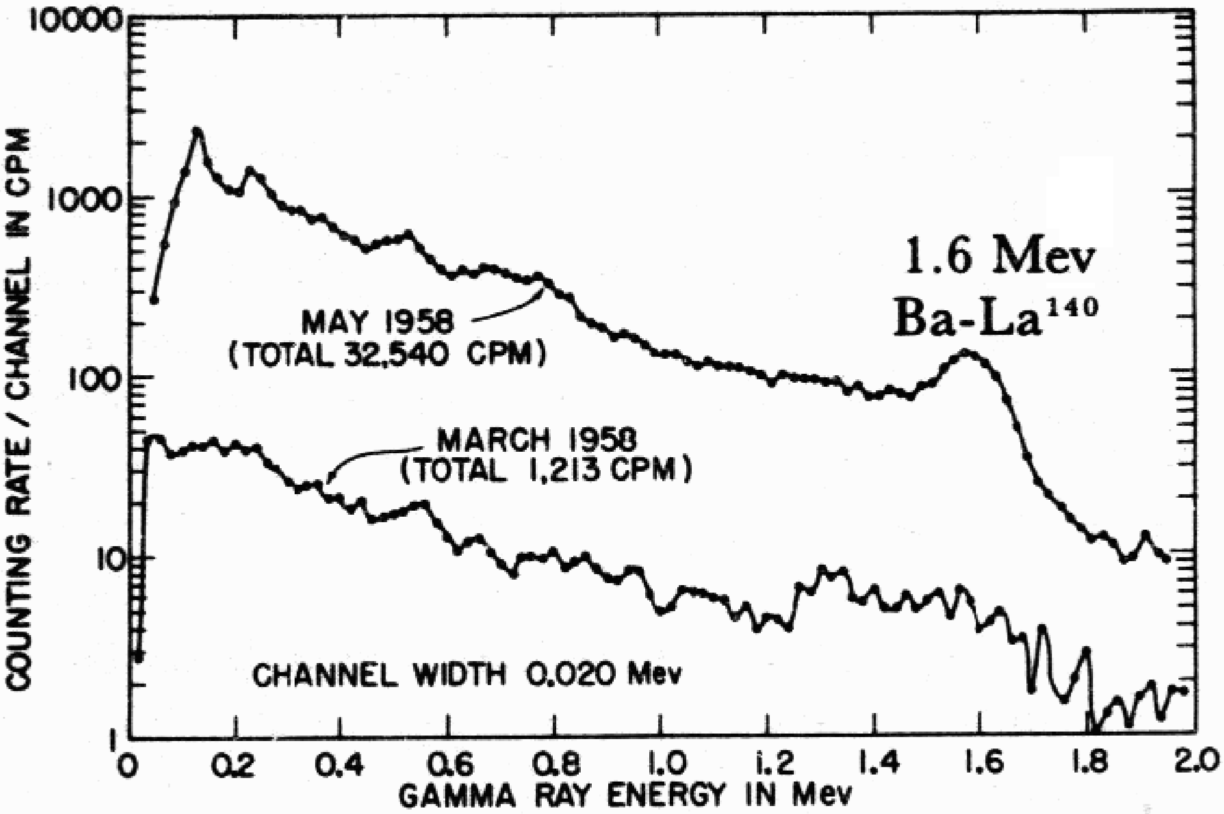


Figure 16. Background counting rates at Rongelap Atoll.

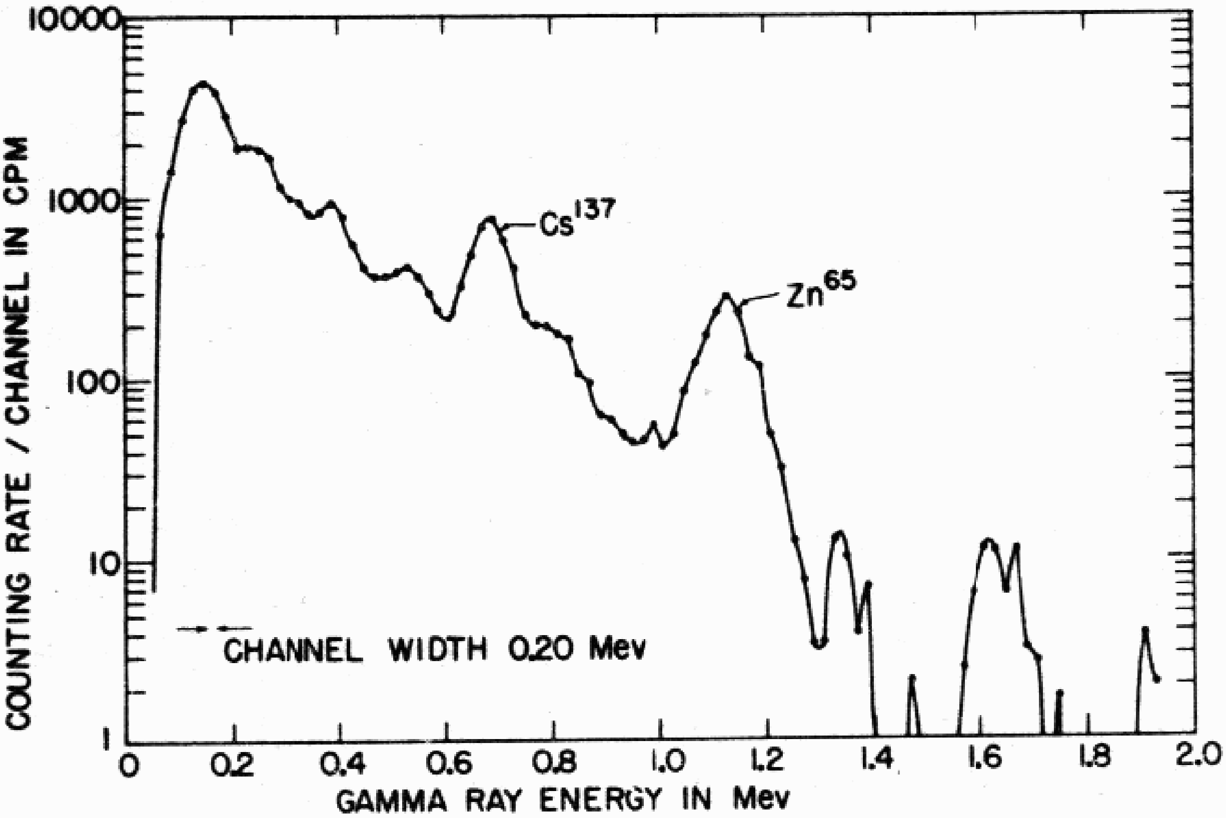


Figure 17. Rongelap subject #50, May 1958, total 43,260 cpm above background.

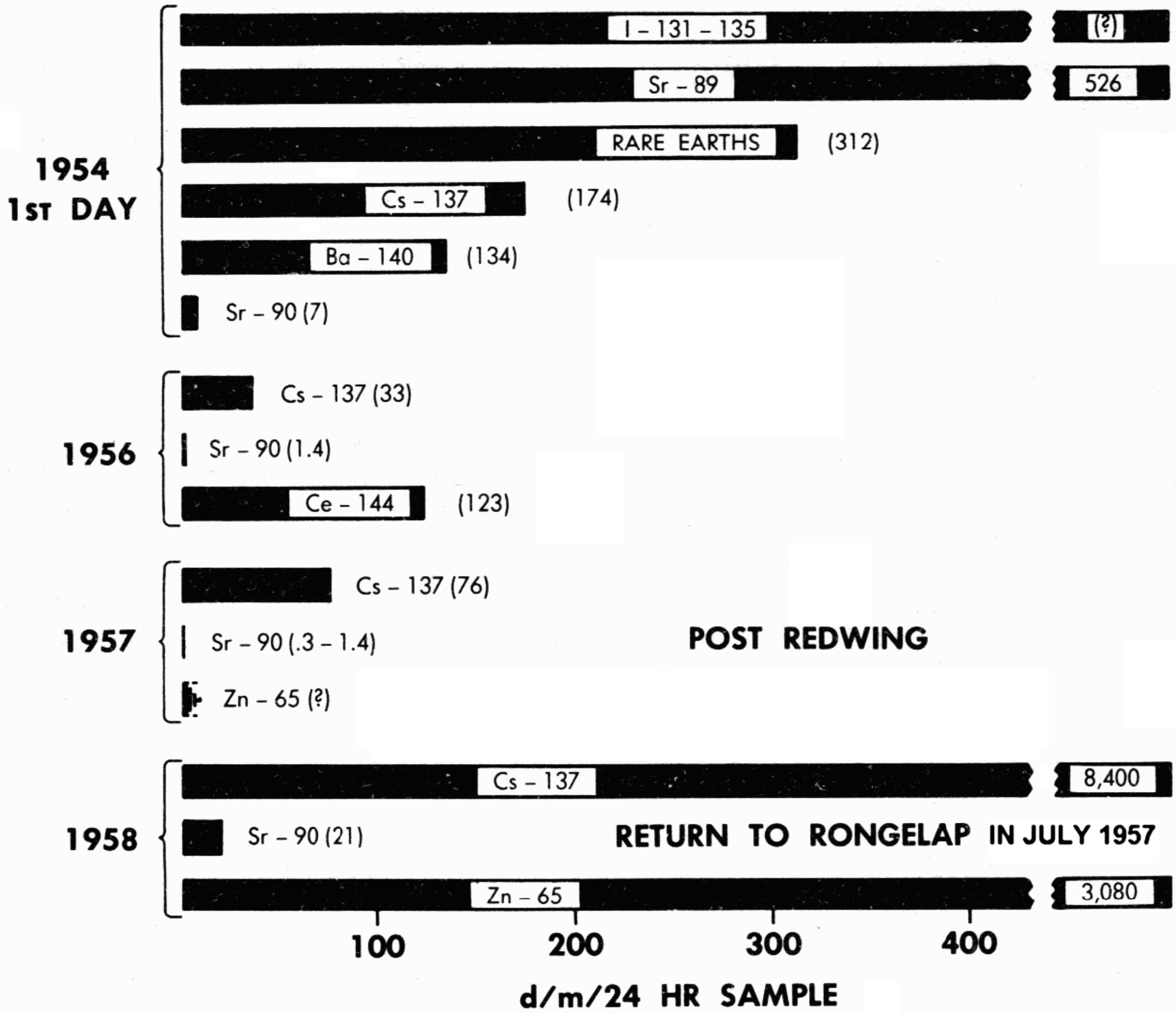


Figure 19. Urinary excretion of isotopes by Rongelap people.

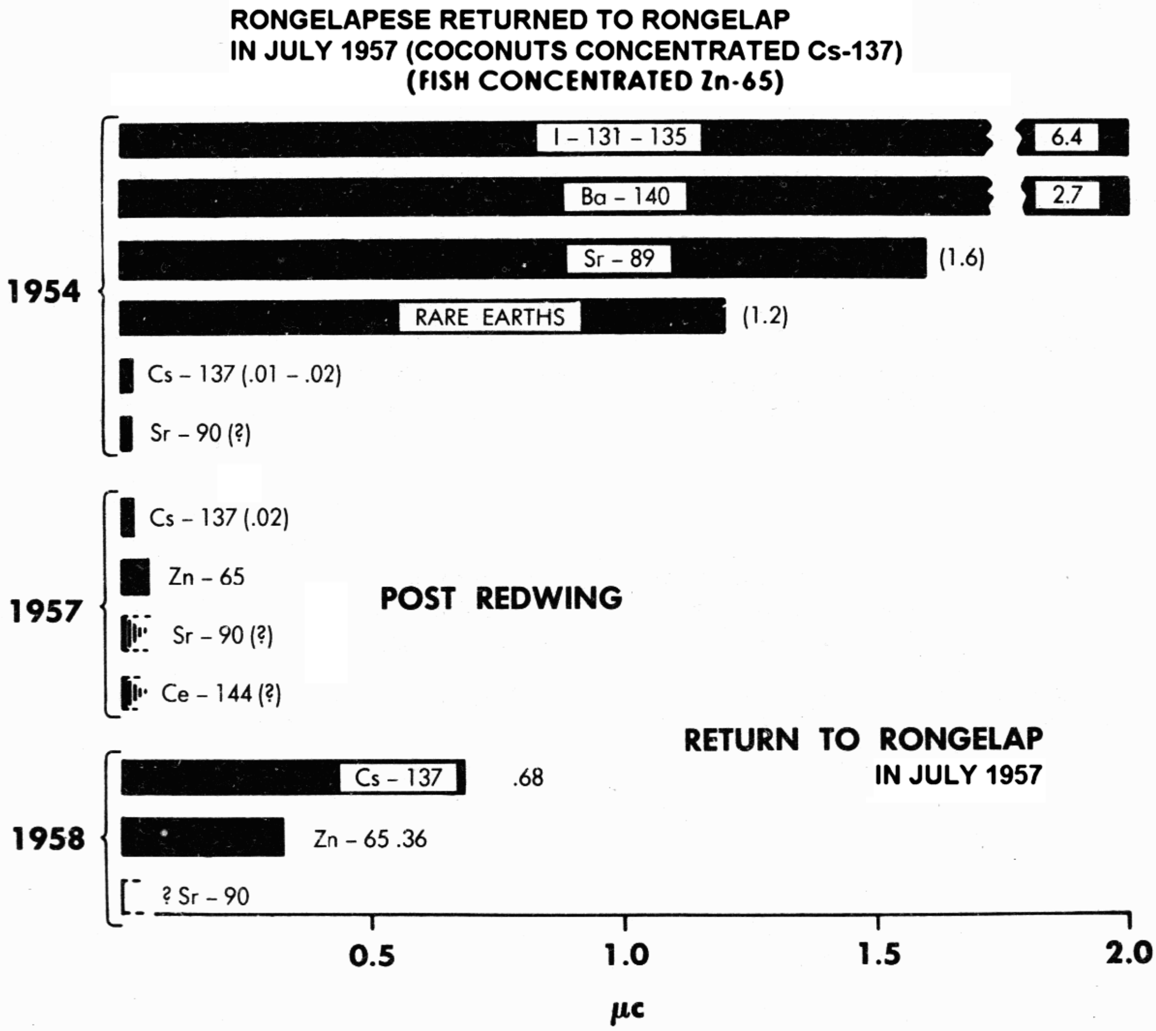


Figure 20. Estimated body burden of isotopes of Rongelap people.

DR DUNNING:

Iodine-131

1. 2 KT/mi^2 -----> 2 x 10^5 curies I^{131}/mi^2

   -----> 7.7 x 10^4 μc I^{131}/M^2

2. Based on Windscale experience

   1 μc I^{131}/M^2 -----> 0.1 μc I^{131}/liter of milk(5)

   For one liter of this milk -----> 2 rad dose to infant's thyroid.*

   For continuous consumption of milk from cows grazing on pasture until I^{131} activity essentially zero -----> 22 - 44 rad dose.*

3. Arithmetically -

   (7.7 x 10^4) (22-44) -----> (1.7-3.4) x 10^6 rads total dose to thyroid of children.

4. Based on data from nuclear weapons tests, the cow's thyroid might theoretically receive a dose two orders of magnitude higher than the numan.(6)

   Actually, of course, the external gamma exposure and the dose to the cow's digestive organs would guarantee its death. If milk were obtained before its death there might be enough I^{131} activity in a single pint of milk to completely destroy the infant's thyroid.

   (7.7 x 10^4) (1-2 rads) -----> (7.7-15) x 10^4 rads

The short-lived isotopes of radioiodine could contribute more dose to the thyroid than does I^{131} for the first day or so, but their activity would decrease rapidly with time.(7) Milk as a food item should be avoided until the iodine activity levels dropped to acceptable limits, or canned or powdered milk (prepared before the fallout occurred) should be substituted.

5. If one assumes all contaminated milk is eliminated from the diet there remains the general I^{131} contamination of the environment including exposed foods and water.

The principal potential source of intake of the I^{131} would be leafy vegetables and other similarly exposed foods. This I^{131} contamination would be reduced by washing the foods, since the water supply would be expected to contain less I^{131} activity due to dilution factors. However, the reduction would have to be considerable since a single intake of I^{131} from one square meter of surface during the first week after the fallout occurred might produce a thyroid dose of more than 10^5 rads to the adult thyroid. It is not being postulated here that persons normally lick over a square meter of surface, but it illustrates the very heavy contamination that might exist in the environment, and that prevention of entry of significant amounts into the body would be a serious consideration.

6. Based on radiological decay only, it would require about 80 days for the I^{131} activity to decay by a factor of 1000. Even considering weathering effects it is doubtful if pasture lands would be useable by then, since doses in the order of a few hundred rads to the infant's thyroid may be carcinogenic.(8)

D. Strontium-90

1. General.

   2 KT/mi^2 -----> 200 curies Sr^{90}/mi^2

   Due to fractionation there may be 2 - 3 times less than this for the close-in areas, i.e. 67-100 curies Sr^{90}/mi^2

2. 80 mc/mi^2 -----> 8 S.U. in children (in equilibrium)* (17) or 10 mc/mi^2 ----> 1 S.U. in children. This is based on U.S. diet including milk as a major source of calcium. Use of other foods as a source of calcium would increase the Sr^{90} intake due to less discriminatory factors.(18)

3. Using 200 curies Sr^{90}/mi^2 and conversion factor

   10 mc/mi^2 -----> 1 S.U. at equilibrium.

   20,000 S.U. -----> 20 r/yr to bone marrow**

   -----> 470 r in 35 years (assuming(a) mean life of surviving population in 35 years, and a radiological decay of Sr^{90} in environment and in man).***

4. The above estimates do not consider any decontamination measures, selection of lesser contaminated foods for consumption, or use of foods from lesser contaminated areas. One may assume these factors will reduce the above estimates by whatever degree we wish to postulate the effectiveness of the factors.

* Equilibrium in children might be reached in 2 - 3 years. Equilibrium would be approached in adults only after many years and to this extent calculations overestimate the effect.

** This may be a somewhat low estimate.

***The biologically available strontium would be expected to decrease naturally with time faster than its radiological decay would indicate, therefore, the assumption used here tends to overestimate the exposure.

Carbon-14

1. Assume: 1 M.T. (total yield) $\dashrightarrow$ 2×10^{26} neutrons (Outside bomb)
$\dashrightarrow$ 4.7 Kg C^{14}

   If one-half of neutrons "lost" to ground (i.e. surface bursts),

   then $\dashrightarrow$ 2.4 kg. C^{14}/M.T.

2. 3953 M.T. (total yield) $\overset{\sim}{\dashrightarrow}$ 9.3×10^3 kg. C^{14}

3. There are two reservoirs for freshly produced C^{14}:[21]

   4.4% in reservoir A[a] with Tm of 8070 yrs.

   95.6% in reservoir A with Tm of 27.2 yrs.

4. There are 3200 kg. C^{14} normally present in reservoir A[b].

$$\frac{(9.3 \times 10^3)\ (4.4 \times 10^{-2})}{3200} \times 8070 \times 1.5^{(c)} = 1550 \text{ mr}$$

$$\frac{(9.3 \times 10^3)\ (9.6 \times 10^{-1})}{3200} \times 27.5 \times 1.5 = \underline{120 \text{ mr}}$$

$$\underline{\text{Total}} \quad 1670 \text{ mr or} \sim 1.7\text{r}$$

5. Assuming that transmutations account for roughly the same number of genetic defects as does radiation,[22] then: $\sim$3.4 r "effective" over 8000 years.

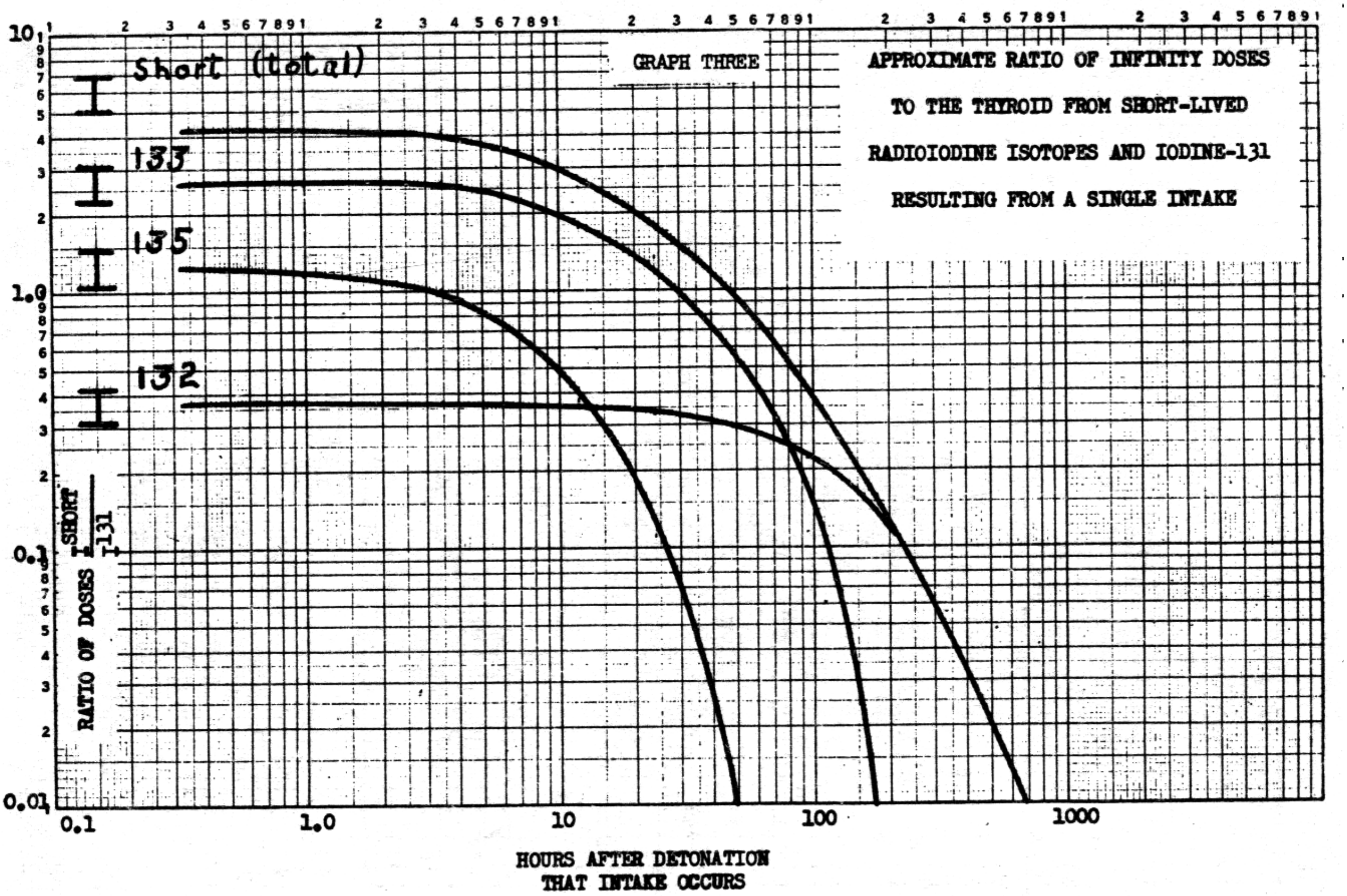
6. During the same period of time (8000 years) the dose from naturally occurring radioisotopes in the environment and from cosmic rays might amount to 800 r (assuming no change in the present rate). The effect from C^{14} would not be zero but would not constitute a problem to the same degree as other factors.

(a) The atmosphere, the land biosphere, and humus.

(b) This assumes uniform distribution over the world which may not be too greatly in error for C^{14}.

(c) Yearly dose from C^{14} present in environment.

***The biologically available strontium would be expected to decrease naturally with time faster than its radiological decay would indicate, therefore, the assumption used here tends to overestimate the exposure.



GRAPH 3

Graph 4 shows the number of microcuries of fission products ingested at times after detonation to produce 1.0 rad to the thyroid.

III. Doses to the Bones

The three principal bone-seeking isotopes of concern are Sr^{90}-Y^{90}, Sr^{89}, and Ba^{140}-La^{140}. Evaluation of these may be made in terms of amount deposited in the bones versus maximum permissible body burdens, or in rads of dose that they deliver after deposition. Since values for maximum permissible body burdens are based on the concept that these will be maintained indefinitely in the body, they are not so valid for Sr^{89} and Ba^{140}-La^{140} when considering short periods of emergency intake.

The following principal assumptions are used in calculating the doses to the bones of adults:

a. The percentages of the isotopes of Sr^{90}-Y^{90}, Sr^{89}, and Ba^{140}-La^{140} in mixed fission products are according to Hunter and Ballou.[3]

b. The percentages of intake of these isotopes that are deposited in the bones, the energies of emissions, and their effective half lives are according to reference five—except for Sr^{90} where a 27.7 year radiological half life is used here.

c. The mass of the bones is 7,000 grams.

The method of calculation of doses to the bones is illustrated by computing the dose from Sr^{89} from the intake of 27 microcuries (See IV Discussion below) of mixed fission products on the 120th hour. Similar calculations were made for Sr^{90}-Y^{90} and Ba^{140}-La^{140} and then the three doses were added for each intake of fallout material.

Step 1. Determine the Sr^{89} to reach the bone.

According to reference 4:

The Sr^{89} content in mixed fission products on the 120th hour is 1.6%.

According to reference 5:

The intake of Sr^{89} to reach to the bones is 25%.

Therefore:

(27) $(0.016)(0.25) = 0.108$, to the bone.

Step 2. Determine the dose rate to the bones.

With an assumed effective energy of 0.55 Mev (reference 5):

$$\frac{(0.108)(2.2 \times 10^{6})(60 \times 24)(1.6 \times 10^{6})(0.55)}{(100)(7{,}000)}$$

$$= 4.3 \times 10^{-4} \text{ rads/day } \textit{or } 0.43 \text{ millirads/day}$$

Step 3. Determine total dose.

D total $= (R/\lambda e)$

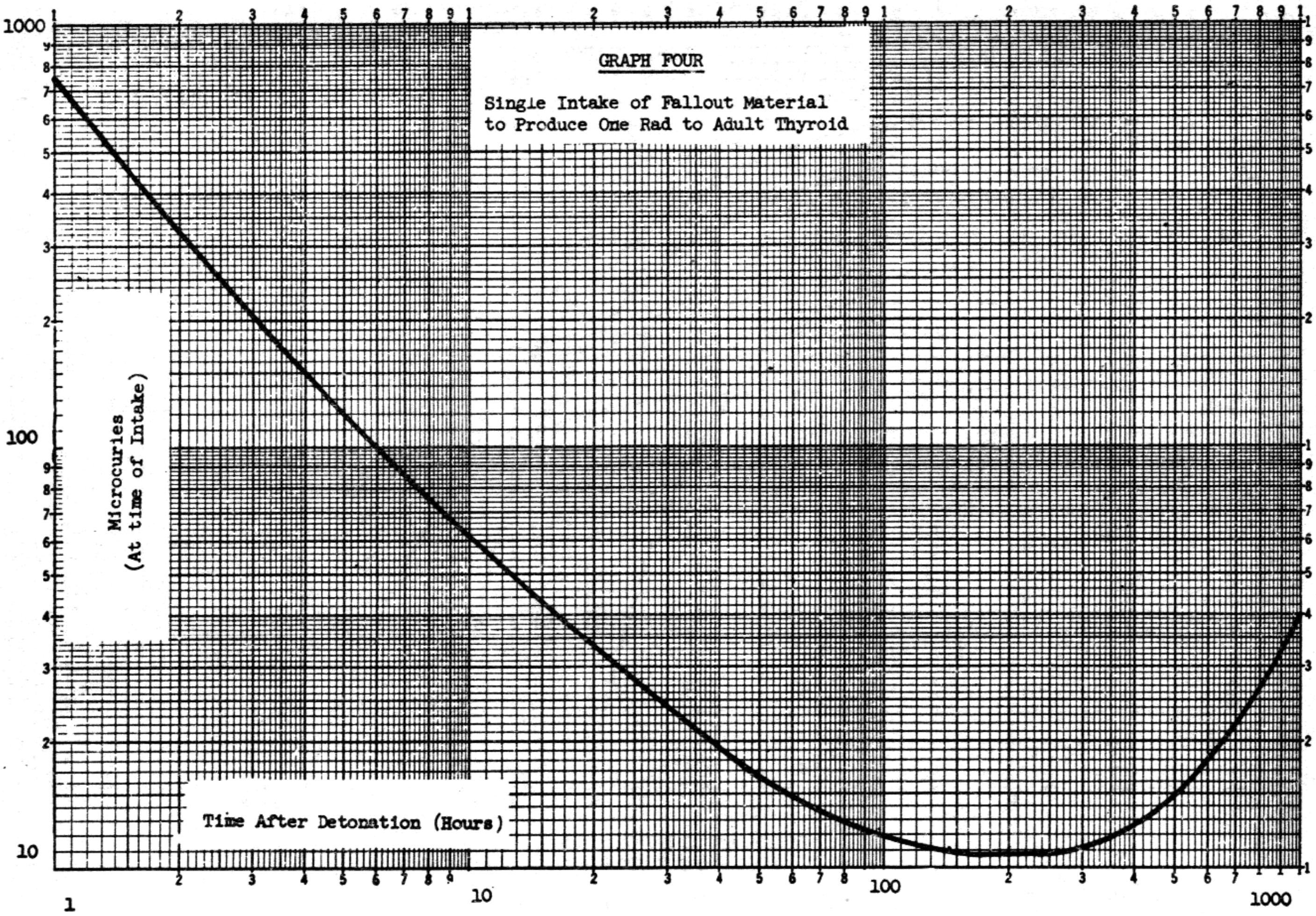
where: R = initial dose rate

λe = effective decay constant

D total $= (0.43/0.0133) \cong 32$ millirads*

* The relative total doses from these isotopes are as follows:

Time of intake	Sr^{90}	Sr^{89}	Ba^{140} — La^{140}
24th hour	0.6	1.00	0.6
20th day	1.00	1.00	0.3



GRAPH 4

IV. Discussion

A. Solubility

The solubility of fallout material varies, depending among other factors upon the surface over which the detonation occurred. The fallout material collected in soil samples at the Nevada Test Site has been quite insoluble, i.e. only a few per cent in distilled water and roughly 20–30 per cent in 0.1 N HCl. However, it would be expected that the activity actually present in drinking water supplies would be principally in soluble form. The water collected from a well and a cistern on the Island of Rongelap (Table III) about 21 months after the March 1, 1954 fallout, was found to have about 80 per cent of the activity in the filtrate, but there was an undetermined amount that settled to the bottom. Other data suggest the material to have been about 10–20 per cent soluble in water.

In the event contaminated food is ingested it is possible that the total activity—soluble and insoluble—may find its way into the gastro-intestinal tract since at times immediately following a fallout most of this activity probably would come from the surface contamination rather than the soil-plant-animal cycle. There may then follow some solubilizing in the acid stomach with subsequent removal from the tract before reaching the lower large intestine.

TABLE III

Concentrations in Water on Islands in the Pacific and Estimated Gamma Dose Rates at D + 1, Three Feet Above Ground

Date	Location	Gross Fission Product Activity (*d/m/*ml)
	Rongelap Island (3.5 roentgens per hour)	
D + 2	Cistern	~50,000–75,000
D + 34	"	~5,500
D + 34	Openwell	~2,000
D + 300	Cistern	~3
D + 330	"	~4
D + 600	"	~5.5
D + 600	Openwell	~0.5
D + 600	Cistern (With collapsed roof)	~1.3
	Kabelle Island (19 roentgens per hour)	
D + 330	Ground water	~48
	Eniwetok Island (8.5 roentgens per hour)	
D + 330	Cistern	~25
	Enibuk Island (1.3 roentgens per hour)	
D + 600	Standing water from can, drum, etc.	~1.4

Representative HOLIFIELD. Dr. Stanton H. Cohn will present testimony on the evaluation of the hazards from inhaled radioactive fallout. Dr. Cohn is presently with the Medical Physics Division, Medical Research Center, Brookhaven National Laboratory. He is a member of the Subcommittee on Inhalation Hazards of the Pathological Effects of the Atomic Energy Radiation Committee of the National Academy of Sciences. He was a member of the U.S. Naval Medical Team which provided emergency medical treatment to the Marshallese accidentally exposed to fallout from operations in 1954. He studied the internal radioactive contamination of the exposed Marshallese. He was also a member of the AEC medical team which made the 5-year medical survey of the Marshall Islands in 1959 and studied the internal radioactive contamination by measuring body burdens of various fission products of 250 Marshallese using a whole body gamma scintillation counter. He participated in the direction of the study of the residual contamination of plants and animals of the Marshall Islands in two surveys in 1955 and 1956.

TESTIMONY OF DR. STANTON COHN,[1] BROOKHAVEN NATIONAL LABORATORY

[1] I. Experience: Scientist, Medical Physics Division, 1958 to present, Medical Research Center, Brookhaven National Laboratory, Upton, Long Island, N.Y. Head, Internal Toxicity Branch, 1950–58, Biomedical Division, U.S. Naval Radiological Defense Laboratory, San Francisco, Calif. Research assistant, 1949–50, Crocker Radiation Laboratory, University of California, Berkeley, Calif. Biochemist, biomedical division, 1946–49, Argonne National Laboratory, University of Chicago, Chicago, Ill. Biochemist, laboratory of the 203d General Hospital, Paris, France, 1943–46, U.S. Army. Chemist, explosives, 1942–43, Kankakee Ordnance Works, Joliet, Ill., and Lake Ontario Ordnance Works, Niagara Falls, N.Y.

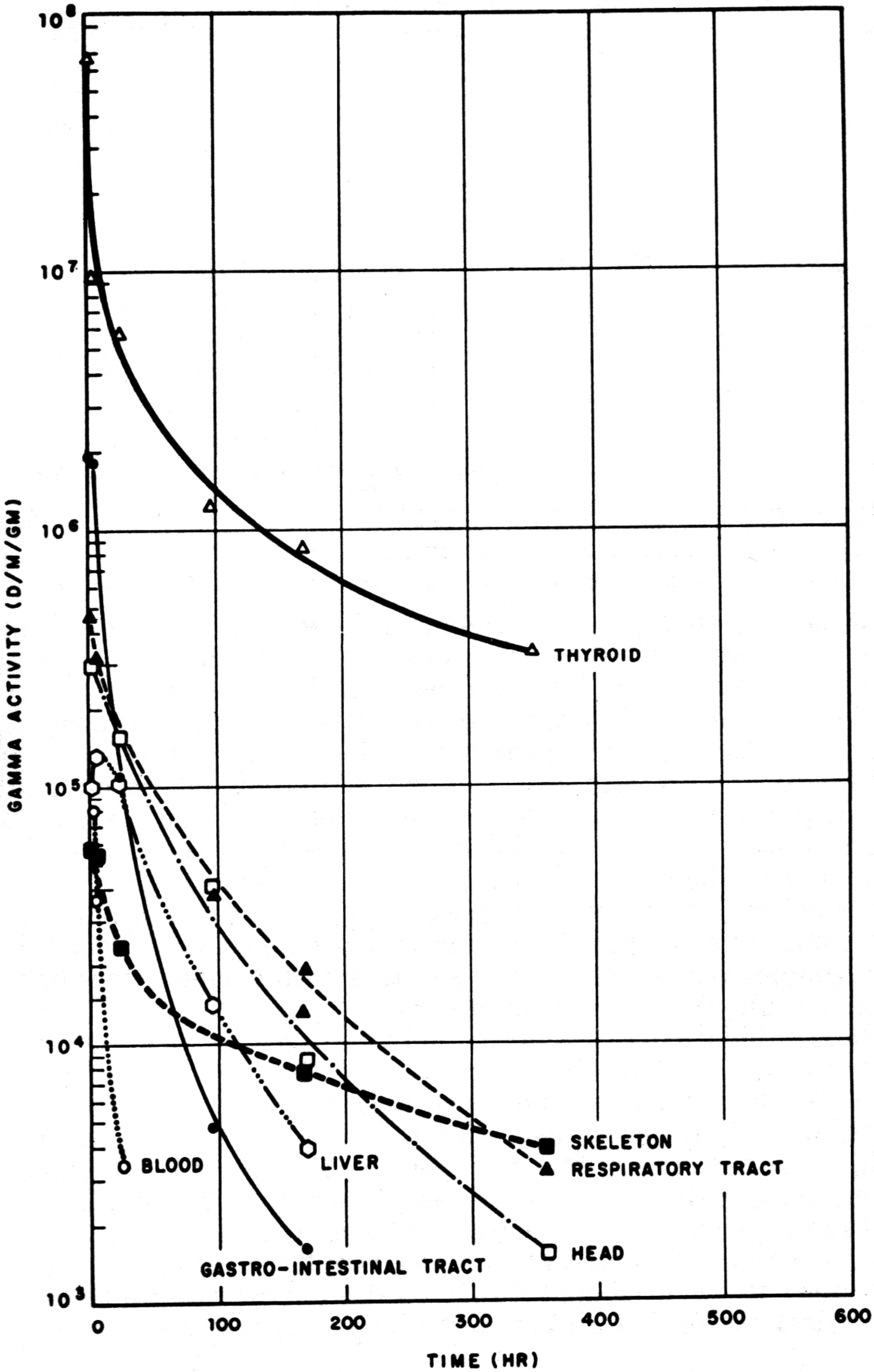
II. Education: University of California, Berkeley, Calif., 1952, Ph. D., physiology-radiobiology (Dr. Hardin Jones and Dr. D. H. Copp). University of Chicago, Chicago, Ill., 1949, S.M., physiology (Dr. Franklin McLean); 1946, S.B., Biochemistry.

III. Additional qualifications: Member of the Subcommittee on Inhalation Hazards of the Pathological Effects of Atomic Radiation Committee, National Academy of Sciences, 1956 to present. Member of the U.S. Navy medical team which provided emergency medical treatment for the Marshall Islanders accidentally exposed to fallout from Operation Castle, March 1954. Studied the internal radioactive contamination of the exposed Marshallese. Also member of the AEC medical team which made the 5-year medical survey of the Marshall Islands in 1959. Studied the internal radioactive contamination by measuring body burdens of 250 Marshallese using a whole body gamma scintillation counter. Participated in the direction of the study of the residual contamination of plants and animals of the Marshall Islands in two field surveys, 1955 and 1956. Member of the Advisory Committee on Civil Defense, 1958.

IV. Scientific Societies, memberships: Radiation Research Society, American Physiological Society.

There is no question that radiation from internal sources can produce lung cancer, but it is not as yet possible to equate the changes produced with given levels of radiation dose. The best estimate of the external dose required to produce pulmonary fibrosis and pneumonitis lies in the range of 800 to 2000 rads, with a mean dose of about 1,000 rads. The induction of pulmonary cancer from radioactive material in experimental animals requires a dose of about the same order. The smallest dose to the lung which produced malignant tumors in mice was reported as 115 rad, following administration of 0.003 μc $Pu^{239}O_2$, and 300 rads after administration of 0.15 μc $Ru^{106}O_2$. However, other studies with mice have indicated that 2,000 rad was the threshold dose for lung tumor formation. Actually, almost all of these studies utilize intra-tracheal administration of the material for experimental ease. It is difficult to compare such an exposure to one deriving from true inhalation.

FIGURE 7



FROM: STANTON H. COHN, "RADIOTOXICITY RESULTING FROM EXPOSURE TO FALLOUT SIMULANT," REPORT USNRDL-TR-118 (1957), FIG. 5.

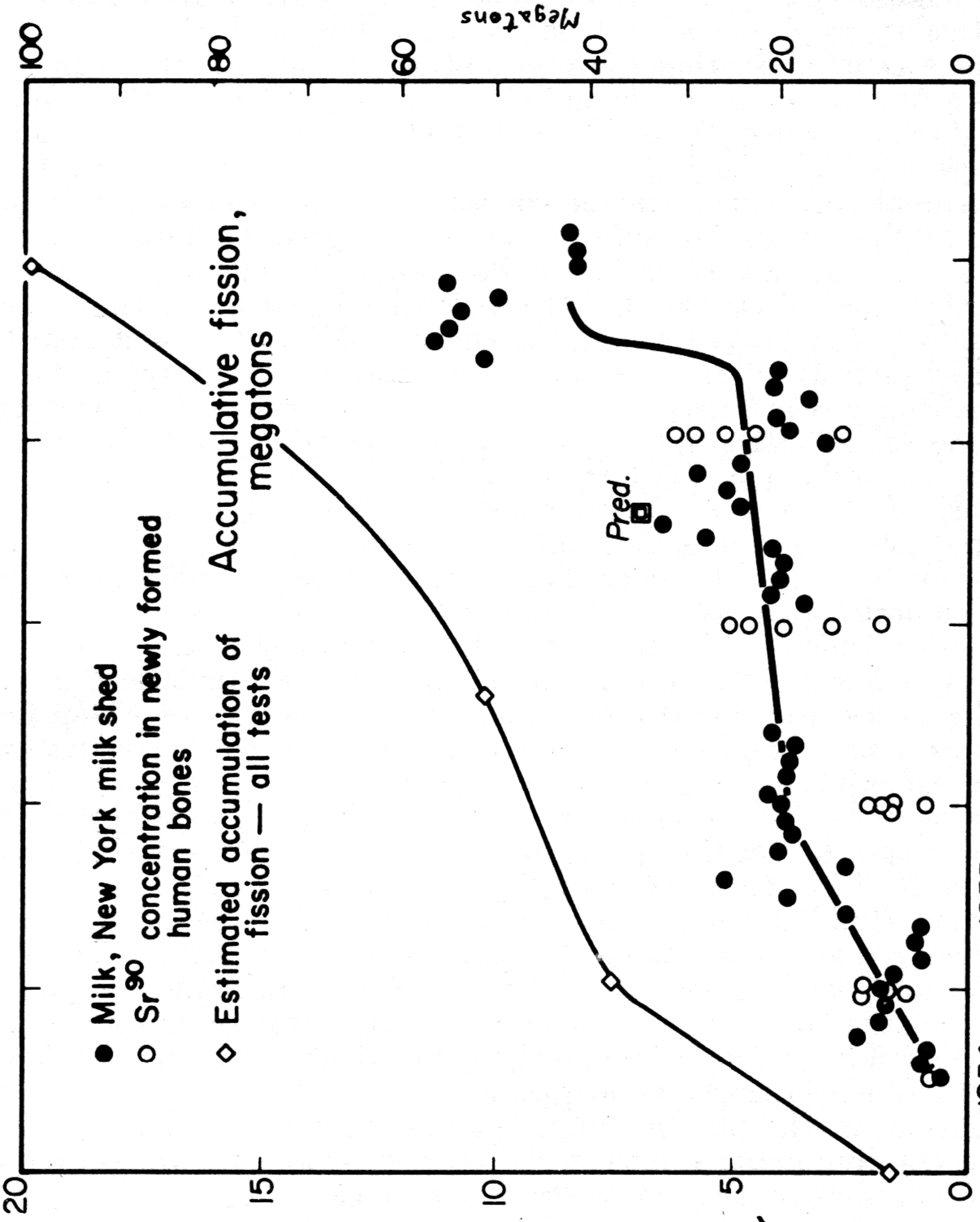
UPTAKE & RETENTION BY MICE OF A SIMULANT OF FALLOUT

PRODUCED BY A LAND BASED NUCLEAR DETONATION.

(MICE WERE EXPOSED TO 2-DAY OLD FALLOUT)

92 fission megatons of tests to end 1958 give a mean of 10 $\mu\mu Ci\ Sr^{90}/gm$ Calcium
=> 28 mR/year to bone in the Northern Temperate Zone.

FIGURE II



($\mu\mu Ci\ Sr^{90}$/gram of bone calcium)
Sunshine or Strontium Units (S.U.s)
Calcium = 1/7th of bone mass.
1 $\mu\mu Ci\ Sr^{90}$/gram of Calcium in bone ≡ 2.8 mR/year

SURVIVAL ARITHMETIC

Heavy Fallout Area: 3000 r/hr at 1 hour

Dose during first year	12,000 Roentgens
Dose during first 2 weeks	10,000 "
Dose between 2 weeks and 1 year	2,000 "

EMERGENCY PHASE

10,000 Roentgens

OPERATIONAL RECOVERY PHASE

2,000 Roentgens

Shelter Shielding Factor	Emergency Dose	Reduction Factor	Operational Recovery Dose
10	1000 Roentgens	10	200 Roentgens
100	100 "	100	20 "
1000	10 "	1000	2 "
10,000	1 "		

Figure 1

43338 O—59——44

Table 1

	Date of Collection, August, 1958	Sr90 Activity (0 - 1" Depth)	
Area	Location	mc/sq mi	μμc/g Ca
Cultivated Agricultural Areas			
Moapa, Nevada	7.7 mi NW	16.3	2.5
St. George, Utah	1 mi SE	14.4	4.5
Enterprise, Utah	0.7 mi N	7.46	8.6
Virgin Undisturbed Area, Fallout Midline Locations			
Moapa, Nevada	8 mi N	142	38.3
St. George, Utah	5 mi N	45.6	406
Enterprise, Utah	9 mi N	41.2	51.2

Effect of plowing on concentration of Nevada bomb test fallout in soil

SOIL DECONTAMINATION:

The addition of lime ($CaCO_3$) and gypsum ($CaSO_4$) to acidic soils low in native Ca reduced Sr^{90} uptake by plants. Greatest inhibition occurred at treatment levels equivalent to from 2 to 5 tons per acre. At these levels $CaCO_3$ reduced Sr^{90} uptake about 60 per cent; $CaSO_4$ caused an 80 per cent reduction. These Ca amendments to the soil had little or no influence on the uptake of Sr^{90} from neutral and alkaline soils.

The uptake of Cs^{137} occurring as a contaminant increased as the K concentration in the soil was reduced by prolonged cropping. The addition of K to contaminated soils low in potassium content reduced the uptake of Cs^{137} by plants. (Potassium chloride should have been applied to Rongelap coconuts in 1959 to reduce cesium-137 in diet, instead of evacuation again.)

These radioecological studies have clearly revealed that (1) biological effect (or hazard) cannot be realistically assessed on the basis of measurement of only the gamma radiation field. Fission products from radioactive debris produced by man can be assimilated by animals with the maximum degree of accumulation not necessarily near the source of the nuclear reaction. Further, within a distance of 400 miles from the Nevada Test Site, the plant foliage is a selective particle collector. There has been no significant accumulation of activity through the root system. (2) Biological availability of fallout debris is strongly influenced by the conditions of contamination and by the physical and chemical nature of the contaminating material and its interaction with environmental factors. (3) Within 200 miles from the Nevada Test Site Sr^{89} and Sr^{90} are estimated to be less than 10 per cent of the total theoretical Sr^{89} and Sr^{90} generated by all detonations at the Nevada Test Site since the Ranger Test Series.

FRACTIONATION OF SR89/90 IN LOCAL FALLOUT

I. Method of Casualty Computation in NDAC Damage Assessment Program

In computing casualties from a hypothetical nuclear attack on the United States, the National Damage Assessment Center computer program assigns each person in the Nation to one of a set of standard locations.[1] These standard locations vary in size from census tracts only a few blocks long in the large cities, through minor civil divisions in the suburbs, to whole counties in sparsely settled areas. To make the computation manageable, even with a high-speed computer, it is necessary to suppose that the entire population of each standard location is concentrated at a central point. Since the standard locations are small in the densely populated areas, this generalization is not regarded as a source of significant error.

Computation of the casualty percentage from direct effects (blast thermal, and direct radiation) is based on the distance from the center of the standard location to the nearest ground zero. The distance associated with a given casualty probability is scaled according to the cube root of the yield.[2] The case where several weapons affect a standard location is handled by applying the largest of the casualty probability percentages caused by any of those weapons. The casualty percentage tables are based on the Hiroshima-Nagasaki data.[3] Percentages of mortalities and of nonmortal casualties are computed. EXAGGERATION !!

Another phase of the program computes the probable fallout dose at points on the map chosen so that no standard location is more than a mile and a half from a reading. The locations and yields of the weapons and the speed and direction of the winds are taken into account. The basic pattern of fallout distribution is taken to be a semicircle upwind and a half an ellipse downwind, with slight distortion from the effect of wind shear at low wind speeds. The downwind distance is scaled directly with the speed of the wind, and the amount of radioactive material is kept constant by dividing the dose rates by this wind scaling factor. Thus as wind speeds increase the contours grow longer and narrower, and the maximum dose rate in the pattern is reduced. For weapons of different yields, the size of the pattern is scaled according to cloud diameters.[4] This fallout contour model was developed with the advice and assistance of Dr. Lester Machta and Mr. Leo Quenneville, the special projects branch of the U.S. Weather Bureau. The lengths and areas of the contours, and hence the amount of radioactive material distributed, are those developed by the Physical Vulnerability Division, Director of Targets, Assistant Chief of Staff, Intelligence, Headquarters U.S. Air Force.[5] The doses from all weapons near enough to affect a point are added together.

The percentages of the population killed and made ill by the fallout dose are computed, taking into account the shielding of the homes, basements, and other places where the people might take cover.[6] The table of residual factors and poplulation distribution used in the June 3, 1959, computations for the Holifield committee were based on estimates by Mr. Gallagher and Mr. Horton of OCDM of the best protection that might be afforded by moving people into the available structures offering the best protection from radiation. The fallout casualty percentage are computed from the effective biological dose, a concept taking

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[1] "National Location Code." Prepared for Federal Civil Defense Administration by Stanford Research Institute. January 1956.

[2] "The Effects of Nuclear Weapons." Department of the Army Pamphlet No. 39–3. May 1957 ; p. 96.

[3] "Vulnerability Functions for Civil Defense Damage Assessment Program." Prepared for Federal Civil Defense Administration by Stanford Research Institute. April 1956 ; pp. 5, 7, 16–20. Secret.

[4] "Close-in Fallout." W. W. Kellogg, R. R. Rapp, and S. M. Greenfield. Journal of Meteorology. February 1957.

[5] "Nuclear Weapons Employment Handbook." Air Force Manual 200–8. HQUSAF ; pp. 101–108.

[6] "Effects of Nuclear Weapons," pp. 470–477. "Nuclear Weapons Employment Handbook," p. 125.

into account the ability of the body to recover from some of the radiation to which it is exposed. This dose was defined by a committee of leading radiologists meeting under OCDM auspices on February 20, 1959.

The direct effects mortalities are computed first, then the fallout mortality rate is applied to those surviving. In this way the program avoids counting the same fatality twice. The same procedure is then followed for the nonmortal casualties from direct effects and from fallout.

II.—The second question related to the average radiation dose to D+90 days. The average for all survivors was 110 roentgens, while the average for noninjured survivors was 60 roentgens.

Representative DURHAM. Mr. Chairman, I want to express my appreciation, and I think the country at large should appreciate the fine work you people have done in trying to educate the public.

I would like to ask whether or not we should continue to do something like this on a yearly basis, to try to further bring to the public the important thing that we face. Do you think it should be done annually, semiannually, or how often?

Mr. QUINDLEN. Sir, I think that the people of the United States certainly at least annually would benefit by having the attention of the Senate and the House of Representatives devoted to this as a recognition of the importance and of the facts of life which are here present; and that this is not a scare business but that this is a realistic problem to which all of us must devote a good amount of attention.

Representative DURHAM. That is exactly what this committee has endeavored to do from the beginnings of the first radiation hearings all the way through, to put the facts in print so that the people can know what is before them.

Representative HOLIFIELD. Mr. Quindlen, many of the members of this committee, all of them I would say, have borne a very heavy burden of responsibility in carrying figures like these and similar ones in our heads for a long time. Many of us feel it is time for the American people to help bear the burden of responsibility of the kind of world we live in and try to help solve the problems. They are difficult problems. Maybe there are no solutions. But the composite understanding of the American people, it seems to me, is an adequate source of intellectual resource to solve almost any problem, provided we are given an opportunity.

Mr. QUINDLEN. Sir, as I indicated in my first presentation on Monday morning, it is our firm conviction that if the public is fully informed, it will take the necessary action. This has been demonstrated many, many times in our history.

Representative HOLIFIELD. Thank you.

STATEMENT OF HERMAN KAHN,[1] CENTER OF INTERNATIONAL STUDIES, PRINCETON UNIVERSITY

Mr. KAHN. I will do my best.

Representative HOSMER. I think, Mr. Chairman, that Mr. Kahn and the people who have worked with him have given this subject the closest scrutiny that it has ever been given. I think we are fortunate indeed to have him before us.

Mr. KAHN. Thank you very much.

Representative HOLIFIELD. I notice that you have been here every day. You have seen a congressional committee in action over a long period of time now. I think you have a concept now of the laborious method by which we put things on record.

[1] Undergraduate work at UCLA. Graduate work at California Institute of Technology. With Rand Corp. for 10 years, November 1958 to present. On leave of absence since January 1959 and now with Center of International Study, Princeton University. Was a consultant to the Gaither Committee; Scientific Advisory Board of the Air Force; Technical Advisory Board, AEC; Office of Civil Defense Mobilization.

This is of some real interest; before World War II, for example, many of the staffs engaged in estimating the effects of bombing overestimated by large amounts. This was one of the main reasons that at the Munich Conference and earlier occasions the British and the French chose appeasement to standing firm or fighting. Incidentally, these staff calculations were more lurid than the worst imaginations of fiction.

Let me give an example. In 1956, there was a revolution in Hungary which the Russians suppressed. There was at that time much pressure on the United States to intervene in that revolution to support the Hungarians. I myself felt rather strongly we should do something. However, I wish to ask the following question: If we had intervened, would the Russians have accepted that intervention, say in 1956? Would they accept it in 1960? These are different situations. It is possible that we did more than not intervene. There are rumors—I do not know if they are true or not—that we broadcast to the East Germans and the Poles not to rock the boat, that American aid was not on the way if they did. There are reasons for worrying about a satellite revolt spreading and, if we had intervened, it is quite clear that there would very likely have been a widespread satellite revolt. Particularly if the Russians did nothing, if they just let us get away with it. After all, some of the satellites revolted without any American intervention.

A satellite revolt is a very big thing to the Russians, and they might not be willing to stand for it. Much more important, the Russians are greatly concerned with internal stability.

What do I mean by this? I mean that if they can evacuate their civilians to places of safety, radiological safety; then we can't kill very many Russians. There are lots of places to evacuate to in the Soviet Union. Let me give some orienting numbers. There are less than 50 million people in the largest 135 Russian cities. As far as we can tell it is perfectly possible to evacute 80 percent of this urban population and have all vital functions in the cities performed. This would leave only 10 million people at risk in 135 cities. Having been alerted, these could evacuate on very short notice. In addition it is very difficult to destroy 135 Soviet cities in a retaliatory blow. I am not saying we could not have done it. I think we could have, in 1956. But it is a difficult thing to do. You can see it is difficult. In any case it is a larger attack than this one.

Even if it did not kill many people such an attack would cause a lot of economic damage in Russia. But the Russians claim to have lost one-third of their wealth in World War II, and they recovered from it. In fact they recovered by 1951. And they know they recovered from such levels of damage, because they mention it. In other words, the Russians know that it can pay to accept very large amounts of damage, rather than to surrender, because they have actually gone through the experience. And while that is a very hard way to learn, it is also a very convincing way to learn by having actual experience. This doesn't mean they would be glad to repeat the experience—only that they may be willing to under less pressure than we would be willing to.

I mention both of these cases, because I want to put the rest of my discussion in context.

One not only has to ask himself what it costs us to go to war under certain circumstances, how do we feel about it, how do the Russians feel about it, how do the Europeans feel about it, but also the same set of questions about the other possibility—about Soviet willingness

Mr. KAHN. I prefer not getting into that debate. I deal in a number of controversial subjects, but I try to keep the number down.

To continue, one might be willing to accept 50 or maybe a hundred, even, strontium units in our children, if we had to. Let us call food that would result in this or lower levels an A food. The A food would be restricted to children and pregnant mothers. One might then also have a B food which might be about 10 times as contaminated as the A food. This would be a high-priced food, available to everybody. There might then be another grade of food, a C food, which would have another factor of 10 more contamination. This would be a cheap food available to all. We are now talking about having up to 10 microcuries in new bone, which is quite a bit.

But I might point out, no one has ever seeen a bone cancer directly attributable to radioactive material in the bone at less than the equivalent of 20 to 30 microcuries. Now, we are reasonably sure that smaller amounts will cause bone cancers in a statistical sense; but I would guess that at least an adult insurance company would not raise its premium very much if one lived on food with that amount of strontium 90 in it. Ten microcuries of Sr^{90} per kg. of calcium would mean a dose of about 20 roentgens a year in the bones.

Then I would suggest another factor of 10 for a D-food, which is not available to the general public but is restricted to people over 40, or maybe over 50. It is difficult to kill a man over 40 or 50 with Sr^{90}. People of this age group do not absorb very much, and it takes 20 or 30 years to get bone cancer. One dies of something else before he does of bone cancer.

One reason why I am suggesting setting up tentative standards now is that we really have to have, before the war, some notion of what we are willing to live with, to guide research, to guide planning, and to eliminate hysteria in a crisis.

There is another reason why it is important to set up in peace the war and postwar standards we think we may have to adopt. In addition to determining these standards, the Government should formally publish them in a permanent looking form that will be available for at least postattack or postcrisis distribution. It is not really necessary to distribute all of the handbooks prewar as people can usually read them either during or after the crisis or attack, though they should be made available to all who are interested. It is, however, important to print them ahead of time, not only so that they will be immediately available, but also so that people will trust the information in them. In any such crisis many will be cynical of the integrity of the Government and will argue that the Government says these standards are acceptable because it must say so, that conditions are such that it has no choice, but that in fact the standards will result in a drastic level of casualties. The knowledge that the standards were set up in peacetime after due care and debate should be reassuring.

I am not suggesting we should publicize the existence and character of the postwar standards. I am not suggesting we should tell everybody they will get bone cancer. I am merely suggesting that the manuals be printed, stockpiled, and a small circulation made to those who are interested.

I had a discussion with a rather senior official in the AEC suggesting this. He looked at me rather amazed. They aren't very happy at the thought of putting out anything that could be construed as suggesting they are underestimating the Sr^{90} problem.

Incidentally, this official asked me, "What do you think the difference in price would be between the B and C foods?"

I said, "About 5 or 10 cents a quart."

He said, "You could not sell one for less than $50 a quart difference."

If it is in fact true that people would not be willing to eat foods contaminated with a microcurie or so of strontium 90 per kilogram of calcium, then I think we are not going to recover very expeditiously from this war.

It is only because, for a short time, we are willing to eat such food, that I believe our recovery would be rapid. If this is not true, then we are either not going to have food, or we will put much energy into obtaining food that should go into other reconstruction projects.

It is important to realize that world agriculture would soon adjust to this problem. We would find the United States growing nonfood crops and meat and Argentina growing dairy products, and so on. In a relatively short period of time, if there is recovery, the patterns of agriculture will adjust to the contamination, and while food may cost a little bit more, it will not be excessive in either price or contamination.

I would like to emphasize: Britain declared war on Germany in 1914. Britain declared war on Germany in 1939. If they had not been able to declare war in either of those 2 years, they would have had to let the Germans do whatever they wanted to do.

However, it may well be, though, that we will face problems in the near future which are just not solvable by the techniques we have used in the past. In fact, that is true today to some extent. And it may well be that we should start on this new world right now. But it is a mistake to say that the new world has arrived today. It does not seem to be true.

I have a book with me today which I recommend to those who want to exaggerate the impact of thermonuclear war. It is called "Munich: Prologue to Tragedy," by Wheeler Bennet. Among other things Wheeler Bennet discusses why Chamberlain and Daladier folded. When they returned from Munich they were cheered by their people in Paris and London, because war had been averted. Over that weekend some people began to understand that war had been averted by a sellout of the worst sort. And on Monday some few were prepared to criticize. But if you read the debate, you noticed something very significant. The people who criticized Chamberlain and Daladier, with a couple of exceptions, did not criticize them for not going to war; they said, "Hitler was bluffing, and you should have stood your ground."

As far as we can tell, Hitler was not bluffing. The men who were in the room with him could see he was not bluffing. It was easy for the people back home to say he was bluffing, but not for the men who had the decision to make. The German people did not want war. The German Army did not want war. They literally threatened to have a military revolution. But Hitler seems to have been willing to have a war if he couldn't have his way.

We may be asked that same question. If the other man is not bluffing, and he may not be, then we have to ask ourselves, "Are we willing to fight or are we not? Do we have an alternative to peace?" It is just that simple.

It turns out that the chain which brings Sr^{90} into the human body from the fallout to the grass, to the cow, to the milk, to the intestines, to the bone, discriminates against strontium 90 versus calcium.

But from our point of view that damage, though acceptable over 10,000 years, is much less acceptable if it is taken in, say, 20 years. If carbon 14 had a lifetime of only 20 years, you would be much less willing to face the possibility of a war and more willing to appease. And if it was a really big war you could not face it, because you would be getting thousands of roentgens in one generation rather than 50. SPECIFIC ACTIVITY $\propto$ 1/(HALF LIFE)

Representative HOSMER. Before we do go, I would like to call attention that on page 8 ways and means are spoken of to ameliorate a thermonuclear war. They will be in the printed hearings.

(The prepared statement of Herman Kahn follows:)

MAJOR IMPLICATIONS OF A STUDY OF NUCLEAR WAR

Herman Kahn, Rand Corp.

IMPLICATIONS FOR DETERRENCE

U.S. national policy rests on a deterrent strategy. Presumably, deterrence of Soviet attack depends upon Soviet calculations of their risks versus their chances of success. Our study distinguishes three types of deterrence in examining the implications of nonmilitary defense:

Type I—Deterrence of a direct attack on the United States. In this case any calculation the Soviets might make would assume they have the first strike and the United States strikes back with a damaged force. (Calculations ignoring the effects of the first strike and therefore based on the preattack inventory of forces can be very misleading.) The Soviets then ask themselves what damage they are likely to suffer before hostilities end. Here the Soviet Union's estimate of the effectiveness of their passive defense preparations may play a crucial role, and the United States should examine these to see what questions they raise. Presumably since the Soviets can count on warning, and because they need only defend themselves against a damaged force, even moderate preparations might be considered effective under some circumstances. It is not that the Soviets could reliably expect to be untouched, but that a situation might arise in which the Soviets might feel that going to war was the least risky of the available alternatives.

Type II—Deterrence of extremely provocative behavior. The Soviets now ask themselves if they can force the United States to accept peacefully the consequences of some extremely provocative action (say a large-scale attack on Europe or a Munich-type crisis).

Type III—Deterrence of moderately provocative actions. In this case it would be wishful thinking to expect deterrence to work most of the time. However, Soviet calculations which contemplate provoking the United States might be influenced by the existence of a U.S. plan for a crash nonmilitary defense program.

INTERACTIONS WITH DISARMAMENT

It may be positively dangerous deliberately to weaken our type II or type III deterrence to the point where it is an invitation to a potential aggressor. Furthermore, even a disarmament program will not completely exclude the possibility of accidental or unpremeditated war. Finally, even the best disarmament agreement might be repudiated or violated—possibly initiating a sequence of events which lead to war. It is, therefore, always necessary either to have capabilities to alleviate the consequences of a war or at least to be able to create capabilities in a short period of time. In general, adequate civil defense capabilities cannot be created in a short period of time unless extensive preparations have been made.

If one is emotionally committed to the belief that deterrence is foolproof, there is not much of a step from being satisfied with a system which is objectively capable of destroying the enemy in a rataliatory blow to a system which can only hurt the enemy, and from there to a system which might hurt the enemy, and finally to one for which there are circumstances in which it is conceivable that the enemy will be hurt. The capacity of Western governments and peoples, under propitious circumstances, to indulge in wishful thinking in the military field is almost unlimited.

A PROPOSED CIVIL DEFENSE PROGRAM [3]

Once one accepts the proposition that it is possible to alleviate, to some extent, the consequences of a thermonuclear war, one is faced with the question, "Is it worth spending money on such a capability?" [3]

[3] Most of the material in this section came from the Rand Corp. Report RM2206–RC, "Some Specific Suggestions for Getting Early Nonmilitary Defense Capabilities and Initiating Long-Range Programs," by Herman Kahn et al. That report was originally prepared in the early part of 1958, and was circulated in a limited fashion to various individuals for information and comment. While I have made some minor modifications in the material to correspond to some changes in my viewpoint, there has been no thoroughgoing revision. The dollar recommendations should be thought of as quantitative expressions of intuitive judgments. However, I should also note that I probably have substantially more justification for my estimates than do many official proposals. In any case, these things are so uncertain, and for reasonable programs the overall performance variations with minor changes in allocations are so small, that as citizen, voter, and taxpayer I am prepared to defend the numerical recommendations, even if as an analyst I have to concede that there is incomplete documentation.

5. There seem to be many possibilities for inexpensive preparatory actions that could result in the creation of important capabilities in the 1965–70 time period. Again, irrespective of any decision to go or not go into a multi-billion-dollar program, these possibilities should be studied; if and when such actions are found desirable they should be put into practice.

A possible allocation for the additional $500 million to be spent on civil defense might go as follows: (This was what Kennedy did in 1961.)

1. Radiation meters	[1] $100,000,000
2. Utilization of existing structures for fallout protection	[1] 150,000,000
3. Preliminary phase (including research and development) of a spectrum of shelter programs	75,000,000
4. Movement, damage control, and anticontamination, etc	[1] 75,000,000
5. Systems studies and planning	20,000,000
6. Other research and development	20,000,000
7. Prototype shelters	20,000,000
8. Education and technical assistance	20,000,000
9. Miscellaneous	20,000,000
Total	[1] 500,000,000

[1] Indicates Federal expenditures that would likely be supplemented by non-Federal expenditures stimulated by the program.

Because of their crucial role, the monitors must obviously be an exceptionally competent and well-informed group of people. However, the monitors do not need and should not have the authority to orient all programs toward prede-

termined objectives. Experience has shown that attempts to conduct large and overcoordinated programs tend to create inflexibility and to stifle new, unproven ideas or independent approaches. Hence, the monitors should act as an advisory group rather than as a "research czar." But they must have the authority to make suggestions and offer criticism at all levels and have the right to contact the researchers or planners in the field.

THE FULL PROGRAM

A superficial description of the $500 million program follows. Somewhat more detail (of a very similar program) can be found in the previously mentioned Rand Corp. report, RM 2206–RC.

1. Radiation meters ($100 million)

Our program calls for 2 million dose-rate meters (at about $20 a meter), 10 million self-reading dosimeters (at about $5 a meter, including an allowance for chargers), and 20 to 50 million dosimeters (at about $1 to $2 a meter).

2. Utilization of existing structures for fallout protection ($150 million)

We would expect about $50 million to be spent on identifying, counting, and labeling the various structures that either provide valuable levels of fallout

4. Movement, damage control, anticontamination ($75 million)

The two main things we should hope to provide under this category are the capability to evacuate to improvised protection and the creation of a core of "reservists" that would be organized to facilitate the evacuation, the improvisation of shelters either pre- or post-attack, and that would also be useful in the immediate postattack and longer run rescue, decontamination, debris clearing, continuity of government, housing, and repair problems. There are at least 5 million people in the United States who have the proper skills for such work.

It might be appropriate at this point to comment on some of the characteristics of good analyses and plans. The following is quoted from RM–1829[5] "Techniques of Systems Analysis," by Herman Kahn and Irwin Mann.

"An item of equipment cannot be fully analyzed in isolation; frequently its interaction with the entire environment, including other equipment, has to be considered. The art of systems analysis is born of this fact; systems demand analysis as systems.

"Systems are analyzed with the intention of describing, evaluating, improving, and comparing with other systems. In the early days many people naively thought that this last meant picking a single definite quantitative measure of effectiveness, finding a best set of assumptions, and then using modern mathematics and high speed computers to carry out the computations. Often their professional bias led them to believe that the central issues revolved around what kind of mathematics to use and how to use the computer.

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[5] A Rand Corp. report.

"With some exceptions, the early picture was illusory.

"In practice, three kinds of uncertainty can be distinguished:

"1. Statistical uncertainty.

"2. Real uncertainty.

"3. Uncertainty about the enemy's actions.

"We will mention each of these uncertainties in turn.

"*Statistical uncertainty.*—This is the kind of uncertainty that pertains to fluctuation phenomena and random variables. It is the uncertainty associated with 'honest' gambling devices. There are almost no conceptual difficulties in treating it—it merely makes the problems computationally more complicated.

"*Real uncertainty.*—This is the uncertainty that arises from the fact that people believe different assumptions, have different tastes (and therefore objectives), and are, more often than not, ignorant.

8. Education and technical assistance ($25 million)

We feel that at least part of the present apathy in the United States is due to ignorance of what can be done or to doubt that anything can be done. This apathy is intensified by the inadequacy of official pamphlets. The problem does not result from security restrictions or inadequate releases of information; official studies themselves are inadequate. Better studies and more definitive Government programs are needed.

It is with some reluctance that I include education in the program. This is not because education is not a very important thing. In particular, in a program that depends a great deal on improvising existing assets, it is probably very important for many people to understand reasonably well what they should do. However, the Government has a tendency to try to depend upon education and paper plans to do everything, rather than to spend even small sums for capabilities that would make the educational program realistic and useful. It is not going to be true that our society can be preserved in a war by individual action supplemented only by Government pamphlets and paper plans. I suspect that the major educational impact will come, not from the formal program of information or propaganda, but simply from the impact of the Government's allotting reasonably large resources to a program that it is willing to defend intellectually.

THREE LECTURES ON THERMONUCLEAR WAR (1960–75) BY HERMAN KAHN

LECTURE I. THE NATURE AND IMPACT OF VARIOUS KINDS OF THERMONUCLEAR WARS

This lecture asks the question, "Is it really true that only an insane man would initiate a thermonuclear war or are there circumstances in which the leaders of a country might rationally decide that war is preferable to any of its alternatives?"

It is concluded that there are plausible, even probable, circumstances in which a country may rationally decide on war as its best alternative. In arriving at this conclusion it is convenient to examine eight distinct phases of a thermonuclear war.

LECTURE II. THE FORMULATION AND TESTING OF STRATEGIC OBJECTIVES AND WAR PLANS

This lecture asks such questions as, "Why and how might a thermonuclear war be initiated? How might it be fought and terminated?"

In discussing these questions it is desirable to distinguish at least three kinds of deterrence:

Type I—The deterrence of direct attack (passive deterrence)
Type II—The deterrence of extreme provocations (active deterrence)
Type III—The deterrence of moderate provocations (tit for tat deterrence)

LECTURE III. WORLD WAR I THROUGH WORLD WAR VIII

Some characteristics of eight wars, real or hypothetical, are analyzed, partly to show relations between strategy, tactics, and technology; and partly to illustrate certain historical themes or possibilities. The eight wars, each a technological revolution ahead of its predecessor, are assumed to have occurred as follows: 1914, 1939, 1951, 1956, 1961, 1965, 1969, and 1973. The historical themes associated with each war are listed below:

1914—An accident prone world miscalculates. Expectations are shattered.

1939—Type II and type III deterrence fail. Expectations are shattered.

1951—A militarily superior nation risks disaster.

1956—Type II deterrence wanes.

1961—The Soviet Union attains "parity." Type II deterrence disappears. Type I deterrence is marginal.

You protect civilians because it is the job of the military to do that and not the job of the civilians to protect the military forces.

It is very important to realize this. Sometimes people forget it. Second, you protect civilians because unless you can do this you are vulnerable to blackmail, either before the attack, during the attack, or after the attack.

Representative HOSMER. How do you use the term "blackmail," Mr. Kahn?

Mr. KAHN. I use the word in the customary sense, where the other side uses threats to influence your behavior and maybe even to make you pay off.

We discussed earlier the possibility that if we cannot accept Russian retaliatory blows, and if it is clear to us, or the Russians, or the Europeans that we cannot accept them, then we may be in a very precarious position.

That is, you have to persuade all three simultaneously. Then we asked ourselves what do we mean by accepting a retaliatory blow, and we noticed the rather different views Europeans and Americans seem to have of the credibility of our initiating actions leading to that possibility. I have no information as to what the Russians would think, none at all.

Mr. KAHN. I would like to make a partial exception to Dr. Libby's remark. Many people object to air and civil defense, not because they underestimate the problem, but because they overestimate it. They think there is nothing significant that can be done to alleviate the consequences of a war.

In other words, the Russians test a missile so some Europeans and Americans act as if they have 500 missiles in existence. This is a human reaction, to look at a trend and anticipate it arrival prematurely.

Dr. TOMPKINS. I would like to put into the discussion if I may just a few personal views of my own as to what the nature of this problem is.

I had the experience of being on the Manhattan District in 1943. I am very familiar with the psychology of revulsion against the effect these weapons can produce.

:he results are catastrophic enough in their own right. They need 1o imaginary amplification. The facts themselves are bad enough. However, it is crucially important to look those facts squarely in the face if one is going to face the necessity for survival, if against your will or despite anything you can do about it, it is imposed on you. As far as I am concerned, if the chips ever go down and avoiding a conflict is not possible in the scheme of human events of the future, I for one do not propose to see this Nation come out the loser.

The world of the future is going to be dangerous. The human capacity to inflict such damage will inevitably be there. The threat of the employment of that damage is something with which we will have to live unless something very drastic changes in our international relations. We must know how to react to it. I personally never exject to see consequences of the type displayed on these maps. If we really thought this, if we really thought that there was no hope of getting around it, then I think one would be entitled to be discouraged.

As far as I am personally concerned, by looking at the problems, understanding what they are composed of, and by necessity being an incurable optimist, I never expect to see a war of this kind happen. It is possible that more limited engagements of a more sharply defined type will be fought under the sword of Damocles hanging over our heads some time in the future. If so, let us be prepared for that. So, that at least, is my personal view as to the role that the nonmilitary defense should play, and it will never be perfect.

Chairman HOLIFIELD. Many of the witnesses who have appeared before this committee this week and the members of this committee have for many months and years been carrying a heavy burden of responsibility of knowledge of these things on their minds and in their hearts.

Some of us have felt that it is time to share this burden of responsibility with the American people. Before we adjourn I want to thank the reporters who have attended these hearings so patiently and the people on the TV and radio, the representatives in those media. I want to thank the members and especially I want to thank Mr. Hosmer, because I believe he sat in his chair as many hours as I have sat in mine.

I want to thank the staff, which has worked on this hearing some 6 weeks. Particularly do I want to thank Colonel Lunger who has worked many nights to 2 and 4 o'clock in order to make these hearings possible the next day and also Dr. Carey Brewer whom we borrowed from another subcommittee, the Subcommittee on Military Operations, for these past few weeks.

I want to thank the audience too that has attended these hearings and compliment them on the way they have listened, attentively and quietly, to the sometimes long, complicated, and technical testimony that has been given in some instances.

These long technical testimonies were necessary in order that the basic record might be presented in as fair a way as we know how.

In conclusion I want to say the challenge of the nuclear age is enormous and inescapable.

The facts of nuclear war and the effects of nuclear war once established will not fade away because they are unpleasant. If we are prudent we will not ignore them.

They will not disappear. Each of us must accept personal responsibilities because the nuclear war is a personal threat to our survival.

The problem is too large to leave solely in the hands of the diplomats and the generals. They need the collective thinking and advice of every thinking human being in the world.

AIR WAR AND EMOTIONAL STRESS

Psychological Studies of Bombing and Civilian Defense

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CHAPTER 2

EMOTIONAL IMPACT OF THE A-BOMB

UNPREPAREDNESS OF THE POPULATION

At both Hiroshima and Nagasaki, disaster struck without warning. Whether intended so or not, an extraordinarily high degree of surprise was achieved by both A-bomb attacks. At the two target cities, prior to the bombing, there had been relatively little anxiety about the threat of heavy B-29 raids. When the planes carrying the A-bomb arrived over their targets, the population was almost completely unprepared. At the time, not even a light air raid was expected. People were caught at home, at work, out on the city streets, calmly going about their usual daily affairs.

When the first A-bomb was dropped, on August 6, 1945, very few residents of Hiroshima were inside air-raid shelters. An all-clear signal from a previous alert had sounded less than half an hour earlier and the normal routine of community life had resumed. Shortly after eight in the morning, when the explosion occurred, the working-class population was arriving at the factories and shops. Many workers were still out-of-doors en route to their jobs. The majority of school children, along with some adults from the suburbs, were also outside, hard at work building firebreaks as a defense against possible incendiary raids. Housewives, especially in middle-class families, were at home, preparing breakfast. Only a few minutes later, their flaming charcoal stoves were to create hundreds of local fires, adding to a general conflagration of such intensity that even if the assiduous labor of Hiroshima's school children had been completed, the fire storm still would have been beyond control.

At Nagasaki, three days later, the populace had heard only vague reports about the Hiroshima disaster. Here again, people were at

work in factories and offices, tending their homes, engaging in their normal daily activities. A few hours earlier a raid alert had been canceled; before the raid signal could be repeated, the bomb had already exploded. Only 400 people out of a population of close to a quarter of a million were inside the excellent tunnel shelters that could have protected some 75,000 people from severe injury or death.

It is generally recognized that the element of surprise was an important factor contributing to the unprecedented casualty rates at Hiroshima and Nagasaki. Many of those who were exposed to lethal gamma radiation, struck down by flying debris, or trapped in collapsed buildings would not have been killed if they had been warned in time to flee to the outskirts of the city or if they had been in adequate shelters. Thousands of people who were out-of-doors or standing in front of windows would have been protected from incapacitating flash burns if they had been under any sort of cover.[1]

Whether or not they suffered severe injury, those who survived the explosion were also affected by the element of surprise in quite another way. The absence of warning and the generally unprepared state of the population undoubtedly augmented the emotional effects of the disaster. "I was just utterly surprised and amazed and awed." This brief remark, by a newspaper reporter who was living in Nagasaki at the time of the disaster, epitomizes the way in which survivors described the terrifying events to which they were so suddenly exposed.

Of great importance in the predispositional set of the population is the fact that there was not a state of readiness to face danger or to cope with the harsh exigencies of a major catastrophe. The stage was well set for extreme emotional responses to dominate the action. It is against this background of psychological unpreparedness that the emotional impact resulting from the atomic disasters should be viewed.

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[1] USSBS Report, *The Effects of Atomic Bombs on Hiroshima and Nagasaki*, U.S. Government Printing Office, Washington, D.C., 1946.

Time from flash to blast = 4 sec at 1 mile:

Although exceedingly brief, this time interval was apparently sufficient for executing some forms of protective action.

A substantial proportion of the respondents in Hiroshima and Nagasaki reported having reacted immediately to the intense flash alone, as though it were a well-known danger signal, despite the fact that they were unaware of its significance at the time. A number of them said that they voluntarily ducked down or "hit the ground" as soon as the flash occurred and had already reached the prone position before the blast swept over them. A Nagasaki housewife told about being suddenly frightened by "something shining in the sky" as she was entering her home; she managed to run into her bedroom "to hide" before the blast wave reached the house and shattered all the windows. A worker in Nagasaki reported that he was out in the street waiting for a streetcar when the big "flash-like electric spark" occurred; he promptly dashed into a nearby public shelter and was inside by the time the blast wave struck. These examples indicate that the atomic flash was not merely an impressive visual stimulus but also, in some cases at least, a danger signal evoking semi-automatic overt responses. The examples culled from the interviews serve to amplify one of the incidental observations mentioned in the USSBS medical report: "Japanese claim that in some instances persons were able to shield their faces with their hands between the time the flash was seen and the time the heat wave reached them."[8]

In the instances cited so far, the prompt action proved to be of a highly adaptive character in that it minimized exposure to the secondary heat and blast waves, preventing burns and concussive blows. The interviews also indicate that this was not always the case. The opportunity to minimize the danger was sometimes missed because the individual remained fixed, staring at the place where he saw the flash, or because the prompt action proved to be wholly in-

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[7] Los Alamos Scientific Laboratory, *The Effects of Atomic Weapons*, U.S. Government Printing Office, Washington, D.C., 1950.

[8] USSBS Report, *The Effects of Atomic Bombs on Health and Medical Services in Hiroshima and Nagasaki*, U.S. Government Printing Office, Washington, D.C., 1947.

appropriate. The following is an example of the latter type of nonadaptive behavior: A young woman in Nagasaki stated that "when I saw the flash of light in the sky I thought it was an incendiary so I started running around looking for water to put it out." It was in the midst of this futile activity that the concussion wave arrived and bombarded her with flying debris.

From the above discussion, it is apparent that some of the survivors immediately perceived the flash as a danger signal. It also appears that for those who were not located near the center there was an opportunity to take protective action that could reduce injuries from the secondary heat wave and from flying glass, falling debris, and other blast effects. It is noteworthy that some survivors evidently failed to make use of this opportunity, as is to be expected when there has been no prior preparation for it.

In a later chapter on the problems of civil defense, we shall have occasion to take account of these findings, since they suggest that casualties in an A-bomb attack might be reduced if the population has been well prepared in advance to react appropriately to the flash of the explosion.

Under such conditions, rapid, uninterrupted flight would generally be the most adaptive response. In the absence of precise, detailed observations of escape behavior, one cannot make an adequate evaluation of the degree of emotional control exhibited by the survivors. To stop and to attempt to extricate others in the face of a rapidly spreading conflagration would sometimes be tantamount to futile sacrifice of one's own life. We cannot be sure, therefore, that those who fled without stopping to help others were behaving impulsively, since we cannot exclude the possibility that they may have been acting on the basis of a realistic appraisal of the danger situation. Our information is too incomplete to permit any fine judgments to be made; from what little is available, it would be unwarranted to conclude that there was a sizeable frequency of inappropriate, negligent, or asocial behavior merely because some instances of abandonment have been reported.

Although Hersey's case material offers little support for the notion that overt panic states were widely prevalent at Hiroshima, it does suggest that under certain local hazardous circumstances, when a large number of people were crowded together, there may have been outbreaks of excited, disorganized group behavior with antisocial consequences. One clear-cut instance of this kind is mentioned by Hersey:

> As Mr. Tanimoto's men worked, the frightened people in the park pressed closer and closer to the river, and finally the mob began to force some of the unfortunates who were on the very bank into the water. Among those driven into the river and drowned were Mrs. Matsumoto of the Methodist school, and her daughter.[30]

A single reference to disorganized group behavior also occurs in one of the eyewitness accounts from Nagasaki: A child who was seven years old at the time of the disaster reports that there was "almost a panic" among the adults in a neighborhood shelter when planes flew over on the night after the bombing.

> The ones near the entrance started pushing to get inside more. They shouted, "Get inside! Move back farther! Let us in, there'll

[30] Hersey, *op. cit.*

> be another flash!" They were so scared! And the ones inside yelled when they got squeezed, because their burns hurt. [Satoru Fukabori's story in *We of Nagasaki*][31]

It should be mentioned that these two incidents are the only examples of group panic or near-panic that were found after a thorough search of all published accounts of the atomic disasters. All the original USSBS interviews from Hiroshima and Nagasaki were also examined. No indications that would suggest the occurrence of mass panic behavior were found in those interviews. A sizeable proportion of the A-bombed survivors do mention that they ran away from the burning city after the explosion, but, in the sparse accounts of themselves and of the people whom they saw, there are no references to excited, uncontrolled behavior that could be characterized as overt "panic."

In only a handful of cases, out of more than a hundred interviewed, is there any allusion to distraught or impulsive behavior that had occurred at least momentarily. The four most extreme examples have already been quoted under "Fear and Terror Reactions," page 21. To these, only a few more could be added, all of which involve only momentary impulsive actions that were immediately brought under control. For example, one woman said that she had been so frightened by the blast that she had already run out of her destroyed house before realizing that her children were left behind, whereupon she immediately returned to the ruins and rescued them.

In contrast to the high percentage of respondents who reported having experienced feelings of fear, less than 10 per cent referred to any action carried out "without knowing what I was doing" or to any other kind of behavior that might remotely imply temporarily disorganized activity.

Obviously, the above negative evidence with respect to panic behavior cannot be taken at face value. There is no way of knowing to what extent the respondents were distorting, suppressing, or repressing their memories of the actual events of the disaster. Since no direct questions were asked about overt actions, some of the

[31] Nagai, *op. cit.*

number of psychiatric patients admitted to hospitals and clinics, nor was there any increase in the incidence of suicides or alcoholic intoxication. For most indicators of mental disorder, the statistics show a decrease rather than an increase. For example, cases of attempted suicide among women (recorded by the police in England and Wales) decreased by 32 per cent during the year of the air blitz (1941), as compared with the prewar rate. Figures on juvenile delinquency, on the other hand, registered a rise during the war years, but, according to Titmuss, these data are not a suitable index of either juvenile or adult neurosis.

The findings cited by the various British writers are based on material obtained from a large number of psychiatrists and medical psychologists, including observers with widely different clinical and theoretical approaches to psychiatric problems. Their methods of investigation ranged from brief psychiatric examinations for purposes of large-scale statistical tabulation to intensive case studies of small groups of patients. Despite the diversity of diagnostic criteria used, there is high agreement that the type of air attacks to which London and other English cities were subjected during World War II did not produce a sizeable increase in major psychiatric disorders.

The available information on psychiatric air-raid casualties among German civilians is consistent with the British findings. At the end of the war in Europe, the Medical Team of the USSBS sent a questionnaire to German psychiatrists and directors of psychiatric institutions. The "universal reply" to the questionnaire was that "neither organic neurologic diseases nor psychiatric disorders can be attributed to nor are they conditioned by, the air attacks."[8]

A parallel survey of relevant specialists on psychosomatic disorders in Germany revealed some definite wartime trends (which will be discussed later in this chapter), but what is relevant here is the general conclusion: ". . . in view of the tremendous exogenous stimuli which offered a fertile ground for the development of psychosomatic complaints, the relative infrequency of the development

[8] USSBS Report, *The Effect of Bombing on Health and Medical Care in Germany,* U.S. Government Printing Office, Washington, D.C., 1945.

admissions for diseases of the nervous system. The statistics from several cities suggest that during periods of bombing there may have been a slight increase in the number of cases with organic and functional psychosis, but this trend is not consistently borne out. Detailed results are presented from only two psychiatric hospitals. One of the hospitals, in Yokohama, showed that there was a *marked increase* in the number of admissions for schizophrenia, general paresis, and other psychoses during May, 1945, the month during which the city received its most severe bombing. The other psychiatric hospital, in Kobe, showed that during the months of severe bombing attacks there was a *decline* in the number of admissions for psychosis and for all other neuropsychiatric disorders. Although some of the Japanese hospital statistics lend themselves to interpretations about possible causal factors, the evidence is not adequate for ascertaining whether bombing produced any significant changes in the incidence of neuropsychiatric cases. In general, the statistical data from Japan do not contradict the observations reported from England and Germany.

The absence of psychiatric casualties following the one air raid on American territory—the Pearl Harbor attack on December 7, 1941—has been described by Weatherby.[11] On the day of the attack, no patients with war neurosis were brought to the hospital that normally served a majority of American troops stationed at Oahu. During the two weeks following the attack, the number of psychiatric admissions was no greater than during the two weeks preceding the attack.

In evaluating the evidence on psychiatric effects of air warfare, it is necessary to recognize that the information is far from complete and that many of the observations are unsystematic and impressionistic in character. Moreover, the statistical studies of psychiatric casualty rates have been criticized on various grounds as underestimating the actual number of psychiatric casualties to be expected among a civilian population exposed to heavy air raids. Vernon[12]

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[11] F. E. Weatherby, "War Neuroses after Air Attack on Oahu, Territory of Hawaii, Dec. 7, 1941," *War Med.*, Vol. 4, 1943, pp. 270–271.

[12] *Loc. cit.*

If the population of a target city is unprotected, the vast majority would undergo traumatizing experiences of personal involvement in an A-bomb attack. It should be recognized, therefore, that the adequacy of civil defense preparations designed to increase the physical safety of the population have a direct bearing on the emotional impact of an atomic disaster. If a target city cannot be warned and evacuated before an attack is launched, if the residents cannot reach adequate shelters, and if well-trained civil defense teams are not available to carry out the essential operations of disaster control, the devastating consequences cannot be counted solely in terms of the inordinate toll of dead and injured people. The less adequate the physical protection of the population, the higher the incidence of emotional shock and disorganized behavior. In an atomic war, such reactions on a mass scale might become a crucial deterrent to national recovery.[3]

To a very large extent, the *morale* of the survivors of an A-bomb attack will be determined by the effectiveness of civil defense measures. During the air blitz against England it became increasingly apparent that the availability of welfare and relief facilities can play a decisive role in minimizing feelings of bitterness, suspicion, free-floating hostility, and other adverse morale effects.

> The rest centres, the feeding schemes, the casualty services, the compensation grants, and the whole apparatus of the post-raid services both official and voluntary occupied this role of absorbing shock. They took the edge off the calamaties of damage and destruction; they could not prevent, but they helped to reduce, a great deal of distress. Like the civil defence services, these schemes encourage people to feel that they were not forgotten. They render much less likely (in William James' phrase) an "unguaranteed existence," with all its anxieties, its corruptions and its psychological maladies.[4]

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[3] The reassurance value and morale-building effects of various military defense measures are greatly in need of detailed study. It should be clear to the reader that the present study has not gone into military plans for active and passive defense of potential targets.

[4] R. M. Titmuss, *Problems of Social Policy.* His Majesty's Stationery Office, London, 1950.

not very useful to assume that "panic" will necessarily be the most probable response.

"Panic" is often used by both popular writers and social scientists as a colorful term to designate any collective dread that is judged to be inappropriate to the occasion. For example, the reactions following the *Invasion from Mars* radio program, which are commonly referred to as panic, consisted mainly of the following: Many people, having tuned in during the middle of the program, heard newscasts and announcements to the effect that some sort of invasion had occurred and that evacuation was necessary; they immediately felt anxious, notified others in their vicinity, phoned members of their families, and in some cases went so far as to carry out the instructions to evacuate.[7] Evidently there were relatively few in the radio audience whose behavior could be characterized as manifestly irrational or antisocial. For most participants, the panic consisted primarily in their reacting to a *false* emergency warning in a manner which, by and large, would have been appropriate for a *genuine* emergency warning, without first checking on its authenticity.

Although "panic" is an extremely ambiguous term, the image it usually brings to mind is that of a wildly excited crowd behaving in an impulsive, completely disorganized fashion, each person abandoning all social values in a desperate effort to save himself. From the available literature on extreme fear reactions, it appears that this sort of behavior rarely occurs unless (1) there is an obvious physical danger which is immediately present (e.g., a raging fire only a few feet away) and (2) there are no apparent routes of escape. Hence, panic, in the limited sense of the term, is likely to be evoked by an A-bomb attack primarily in the area where the disaster actually occurs, e.g., among those who are trapped by the general conflagration within the city. In places which are not affected by the explosion, including the cities which are potential targets for the next attack, there is far less danger of a serious outbreak of overt panic. That is to say, there is a strong likelihood that with appropriate psychological preparation such reactions can be prevented.

[7] H. Cantril, *The Invasion from Mars,* Princeton University Press, Princeton, N.J., 1940.

the Federal Civil Defense agency should have responsibility for releasing basic information and that state and local defense officials should develop an intensive educational program for their own areas.

It can be assumed, therefore, that as part of the general preparedness program there will be some form of educational program on atomic warfare devised to reach the American public. Thus, while one sector of the general population will be receiving intensive special training for the type of civilian defense functions discussed in the preceding chapter, the remainder of the population will also be receiving instruction designed to prepare them to cope with A-bomb emergencies.

OBJECTIVES OF A PUBLIC EDUCATIONAL PROGRAM

That there will be enormous problems involved in attempting to carry out a successful program of mass education becomes apparent as soon as one considers the quantity and the content of the elementary material to be learned. The following is a brief outline of typical items of information which would be essential for the average civilian to know if he is to maximize his chances for survival following an atomic explosion:

1. Appropriate actions during an A-bomb alert: the best place to go if one is at home, at work, out in the open; the best position of the body for protection against blast effects; etc.
2. Appropriate emergency responses to the bright flash of an A-bomb explosion in case of a surprise attack: what the flash will look like; how to avoid injury from the secondary heat wave and the concussion wave; what to do immediately after the concussion wave has passed.
3. Ways of averting fire hazards: how to escape from burning buildings; what to do if one's clothes catch fire; where the safest places of refuge are if one is caught inside the fire area; how the potential fire hazard can be reduced if one

is at the periphery of the explosion; under what conditions one should evacuate to escape from a developing conflagration.

4. Essential precautions against radiological hazards: how to tell whether or not one should remain indoors; how to find an uncontaminated area; which kinds of food are safe to eat and which are unsafe; decontamination rules concerning removal of exposed clothing, scrubbing of exposed parts of the body, etc.
5. Probable location of emergency facilities: nearest medical-aid station if at home or at work; where food, clothing, shelter, and supplies can be obtained after escaping from the disaster area.

The above items pertain only to *individual* survival. If the average person is to be adequately prepared to give the most elementary kind of aid to members of his family and to others, there are many more topics to be included—such as, how to extract a person from beneath debris without injuring him unnecessarily; how to carry injured persons; how to give emergency first aid for burns, cuts, broken bones.

Certain kinds of technical information might also be included. For instance, in order to reduce confusion about the large number of "do's" and "don'ts" concerning radiological hazards—and to prevent the undesirable extremes of irrational indifference and excessive fear—it will probably be helpful to give some basic information about the nature of the radioactivity emitted by an A-bomb explosion. Perhaps by presenting the material pictorially and graphically, so as to reify the radioactive particles, people will come to regard them as a familiar and real part of the physical world. Conceivably, this material might be supplemented by training in certain types of technical "know-how."

It may turn out to be feasible to mass-produce various kinds of radiological safety equipment at a relatively low cost: detection meters, film badges to register total amount of personal exposure, gas masks or respirators, canvas suits and boots, etc.

~~RESTRICTED~~ For PRO

3 OCTOBER 1963

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RESEARCH ON BLAST EFFECTS IN TUNNELS

With Special Reference to the Use of London Tubes as Shelter

by F. H. Pavry

Summary and Conclusions

The use of the London tube railways as shelter from nuclear weapons raises many problems, and considerable discussion of some aspects has taken place from time to time. But - until the results of the research here described were available - no one was able to say with any certainty whether the tubes would provide relatively safe shelter or not.

This research, consisting of a series of model experiments, has demonstrated that the risk from blast in the tubes would be less than the risks above ground. The results are considered to be consistent enough to provide a good estimate of full-scale conditions, and reliable enough to be used as a basis for Home Office shelter policy regarding the London tube railways.

Introduction

When the Advisory Group on Structural Research for Civil Defence was formed in 1957, the Chairman recommended that a study of the effects of blast on tunnels should be one of the main research projects. The relevant paragraphs of his proposals(1) for a research programme were:-

> "In any consideration of tunnels as shelter the crucial problem is the entry of blast, either through existing openings or from a crater formed by a ground-burst bomb. It is particularly important to know if the collapse of a tunnel by earth shock would prevent the blast from entering it, and also whether the collapse would provide a seal against the entry of water from the crater. It is probable that some data could be derived from model experiments using H.E. charges. But it is for consideration whether the results would be so conclusive that the behaviour of full-size tunnels when damaged by megaton weapons could be forecast with the confidence that a major shelter programme would demand."

At the second meeting(2) the Group agreed that model experiments with H.E. charges would be worthwhile, and that the Atomic Weapons Research Establishment (A.W.R.E.) should carry out this research, which has now been accepted by the Advisory Group as successfully completed. A summary record of the progress follows.

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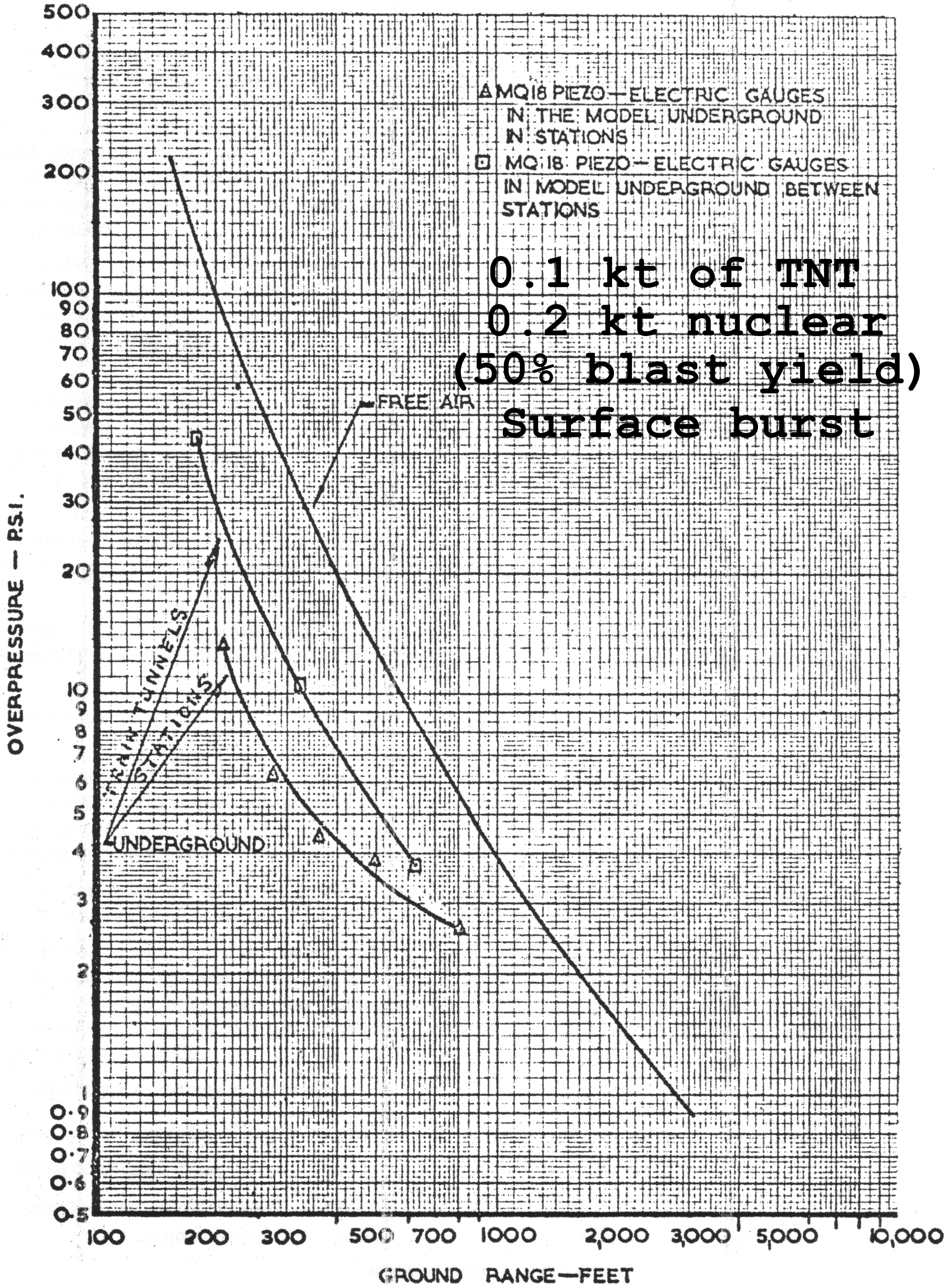
100 ton TNT test on 1000 ft section of London Underground tube at Suffield, Alberta, 3 Aug 1961



Atomic Weapons Research Establishment, "1/40th Scale Experiment to Assess the Effect of Nuclear Blast on the London Underground System", Report AWRE-E2/62, 1962, Figure 30. (National Archives ES 3/57.)

These trials are described in a preliminary report[5] prepared for the Advisory Group by A.W.R.E. It was shown that the blast pressure inside a tunnel system, having openings at intervals to ground level, is less than the pressure at ground level at any distance from the explosion, by a factor of about 3. This reduction in pressure was apparently caused by the station entrances acting as expansion chambers. This observation was of outstanding significance to the consideration of London tubes as shelter.

All previous research on blast in tunnels - and a great amount of work was done on this in the last war - had been conducted with blast entering the open end of a tunnel without side openings. This research had shown that the blast, once it had got into a tunnel, tended to travel great distances without appreciable diminution. This had, therefore, led to the general belief that the London tubes could be death traps rather than shelters.

The more recent research here described showed for the first time that a person sheltering in a tube would be exposed to a blast pressure only about $\frac{1}{3}$ as great as he would be exposed to if he was above ground. (In addition, of course, he would be fully protected from fallout in the tube.)

In fact A.W.R.E. carried out two further tests, with more accurate scaling of station volumes based on more detailed information from the London Transport Executive. A full report on all four tests is in preparation.

These later tests showed that the pressure in station tunnels was only about 1/6th of the ground-level pressure, but that the reduction was not so great in the smaller-diameter train tunnels.

At this stage the Advisory Group were reasonably satisfied that this problem - of blast entry from stations - had been solved. But the other major question of blast entry direct from the crater remained in doubt, on account of the very small scale of the tests to date. Therefore, when the opportunity arose of testing at a really large scale at Suffield, Canada, it was naturally accepted.

Large-Scale Field Test (1/40) at Suffield, Alberta

The test is fully described in an A.W.R.E. report[6]. The decision of the Canadian Defence Research Board to explode very large amounts of high explosive provided a medium for a variety of target-response trials that was welcome at a time when nuclear tests in Australia were suspended. A.W.R.E. used the 100-ton explosion in 1961 to test, among other items, the model length of the London tube, at 1/40th scale, that had already been tested at 1/117 scale.

Blast Entry from Stations

There was remarkable agreement with the 1/117th scale trials: "maximum overpressure in the train tunnels was of the order of $\frac{1}{3}$rd the corresponding peak shock overpressure in the incident blast. The pressures in the stations were about 1/6th those in the corresponding incident blast .... ". In comparing the results at the two scales it was noted that the pressures in the train tunnels (between stations) was higher at Suffield than at the smaller scale; this may, the report suggests, have been due to some blast entry from the crater at Suffield.

Blast Entry from the Crater

There may - as has just been noted - have been some entry of blast at the crater. But the all-important fact is that it was nowhere enough to bring the pressure in the tunnel up to more than a $\frac{1}{3}$rd of the free-air pressure (see fig. 30 reproduced, and attached to this note.) From this, and from a detailed study of tunnel rings ejected by the explosion over a wide area, it can be concluded that the instantaneous crushing of the tube near the crater sealed it against the entry of any significant blast pressure.

Air Flow in Stations

The Report indicates that there would be turbulence generated by blast entry at stations and that there would be a danger to occupants there, on account of blast "windage" acting on them and on missiles that could injure them. This danger would be less in the train tunnels between stations.

Conclusion

The Advisory Group discussed the Suffield Test on tunnels on Nov. 1st 1962, and concluded that model experiments have successfully demonstrated that the risks from blast inside the London tubes would be less than above ground. The Group considered that the results obtained were consistent enough to provide as good an estimate of full-scale effects from megaton weapons as was likely to be obtainable, and that the Chairman could advise the Home Office confidently on the basis of these results. The Group accepted that there would be a risk of casualty-producing air flow in stations, but decided to defer a decision on whether further research on this problem would be profitable. The Chairman said that he would first convey the results of the completed research to the Shelter Division of the Home Office before asking the Group whether it was worth studying this remaining, but less important, problem.

3rd October, 1963.

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Protective Structures

for

CIVILIAN POPULATIONS

1966

MODEL ANALYSIS

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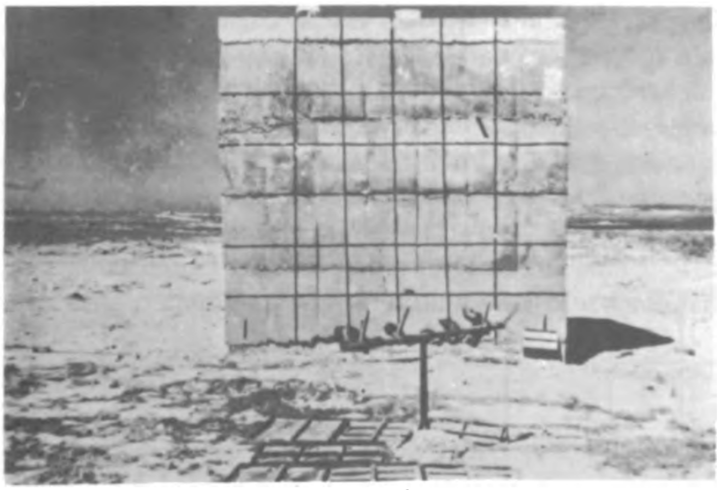
Ralston, Alberta, Canada

Nuclear-Weapon Tests

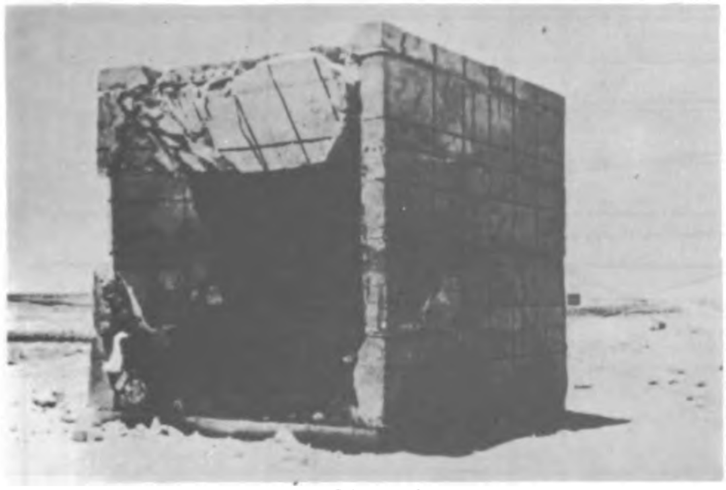
In 1952 we fired our first nuclear device, effectively a "nominal" weapon, at Monte Bello, off northwest Australia. To the blast loading from this weapon we exposed a number of reinforced-concrete cubicle structures that had been designed for the dynamic loading conditions, and for which we made the best analysis of response we were competent to make at that time. Our estimates of effects were really a dismal failure. The structures were placed at pressure levels of 30, 10, and 6 psi, where we expected them to be destroyed, heavily damaged with some petaling of the front face, and extensively cracked, respectively. In fact, the front face of the cubicle at 30 psi was broken inwards; failure had occurred along both diagonals, and the four triangular petals had been pushed in. At the 10-psi level, where we had three cubicles, each with a different wall thickness (6, 9, and 12 in.), we observed only light cracking in the front face of that cubicle with the least thick wall (6 in.). The other two structures were apparently undamaged, as was the single structure at the 6-psi level.

In 1957, the first proposals were made for the construction of the underground car park in Hyde Park in London. The Home Office was interested in this project since, in an emergency, the structure could be used as a shelter. Consequently a request was made to us at Atomic Weapons Research Establishment (A.W.R.E.) to design a structure that would be resistant to a blast loading of about 50 psi, and to test our design on the model scale.

Using the various load-deformation curves obtained in this test, an estimate was made of the response of the structure to blast loading. Of particular interest was the possible effect of 100 tons of TNT, the first 100-ton trial at Suffield in Alberta.



10 p.s.i.



34 p.s.i.

Dynamic tests, Monte Bello cubicles.

A total of seven more models was made; six were shipped to Canada and placed with the top surface of the roof flush with the ground and at positions where peak pressures of 100, 80, 70, 60, 50, and 40 psi were expected. The seventh model was kept in England for static testing at about the time of firing. The results were not as expected. In the field, the four models farthest from the charge were apparently undamaged; we could see no cracking with the eye, nor did soaking the models with water reveal more than a few hair cracks. The model nearest the charge was lightly cracked in the roof panels and beams, and one of the columns showed slight spalling at the head. This model had been exposed to a peak pressure of 110 psi.

BLAST AND OTHER THREATS

Harold Brode
The RAND Corporation, Santa Monica, California

Chemical High-Explosive Weapons

As in past aerial warfare, bombs and missiles carrying chemical explosives to targets are capable of extensive damage only when delivered in large numbers and with high accuracy.

Biological Warfare

Most biological agents are inexpensive to produce; their effective dissemination over hostile territories remains the chief deterrent to their effective employment. Twenty square miles is about the area that can be effectively covered by a single aircraft; large area coverage presents a task for vast fleets of fairly vulnerable planes flying tight patterns at modest or low altitudes. While agents vary in virulence and in their biologic decay rate, most are quite perishable in normal open-air environments. Since shelter and simple prophylactic measures can be quite effective against biological agents, there is less likelihood of the use of biological warfare on a wholesale basis against a nation, and more chance of limited employment on population concentrations —perhaps by covert delivery, since shelters with adequate filtering could insure rather complete protection to those inside.

Chemical Weapons

Chemical weapons, like biological weapons, are relatively inexpensive to create, but face nearly insurmountable logistics problems on delivery. Although chemical agents produce casualties more rapidly, the greater amounts of material to deliver seriously limit the likelihood of their large-scale deployment. Furthermore, chemical research does not hold promise of the development of significantly more toxic chemicals for future use.

Radiological Weapons

The advantages of such modifications are much less real than apparent. In all weapons delivered by missiles, minimizing the payload and total weight is very important. If the total payload is not to be increased, then the inclusion of inert material to be activated by neutrons must lead to reductions in the explosive yield. If all the weight is devoted to nuclear explosives, then more fission-fragment activity can be created, and it is the net difference in activity that must be balanced against the loss of explosive yield. As it turns out, a fission explosion is a most efficient generator of activity, and greater total doses are not achieved by injecting special inert materials to be activated.

Perret, W.R., Ground Motion Studies at High Incident Overpressure, The Sandia Corporation, Operation PLUMBBOB, WT-1405, for Defense Atomic Support Agency Field Command, June 1960.

The Neutron Bomb

The neutron bomb, so called because of the deliberate effort to maximize the effectiveness of the neutrons, would necessarily be limited to rather small yields—yields at which the neutron absorption in air does not reduce the doses to a point at which blast and thermal effects are dominant. The use of small yields against large-area targets again runs into the delivery problems faced by chemical agents and explosives, and larger yields in fewer packages pose a less stringent problem for delivery systems in most applications. In the unlikely event that an enemy desired to minimize blast and thermal damage and to create little local fallout but still kill the populace, it would be necessary to use large numbers of carefully placed neutron-producing weapons burst high enough to avoid blast damage on the ground, but low enough to get the neutrons down. In this case, however, adequate radiation shielding for the people would leave the city unscathed and demonstrate the attack to be futile.

The thermal radiation from a surface burst is expected to be less than half of that from an air burst, both because the radiating fireball surface is truncated and because the hot interior is partially quenched by the megatons of injected crater material.

SUPERSEISMIC GROUND-SHOCK MAXIMA (AT 5-FT DEPTH)

Vertical acceleration: $\alpha_{vm} \simeq 340\,\Delta P_s/C_L$ ± 30 per cent. Here acceleration is measured in g's and overpressure (ΔP_s) in pounds per square inch. An empirical refinement requires C_L to be defined as the seismic velocity (in feet per second) for rock, but as three fourths of the seismic velocity for soil.

OUTRUNNING GROUND-SHOCK MAXIMA (AT ~10-FT DEPTH)

Vertical acceleration: $\alpha_{vm} \simeq 2 \times 10^5/C_L r^2$ + factor 4 or -factor 2. Acceleration is measured in g's, and r is the scaled radial distance—i.e., $r = R/W^{1/3}$ kft/(mt)$^{1/3}$.

Data taken on a low air-burst shot in Nevada indicate an exponential decay of maximum displacement with depth. For the particular case of a burst of ~ 40 kt at 700 ft, some measurements were made as deep as 200 ft below the surface of Frenchman Flat, a dry lake bed, which led to the following approximate decay law, according to Perret.

$\delta = \delta_0 \exp(-0.017D)$,

where δ represents the maximum vertical displacement induced at depth D, δ_0 is the maximum displacement at the surface, and D is the depth in feet.

THE PROTECTION AGAINST FALLOUT RADIATION AFFORDED BY CORE SHELTERS IN A TYPICAL BRITISH HOUSE

Daniel T. Jones
Scientific Adviser, Home Office, London

Protective Factors in a Sample of British Houses (Windows Blocked)

Protective Factor	Percentage of Houses
< 25	36%
25-39	28%
40-100	29%
> 100	7%

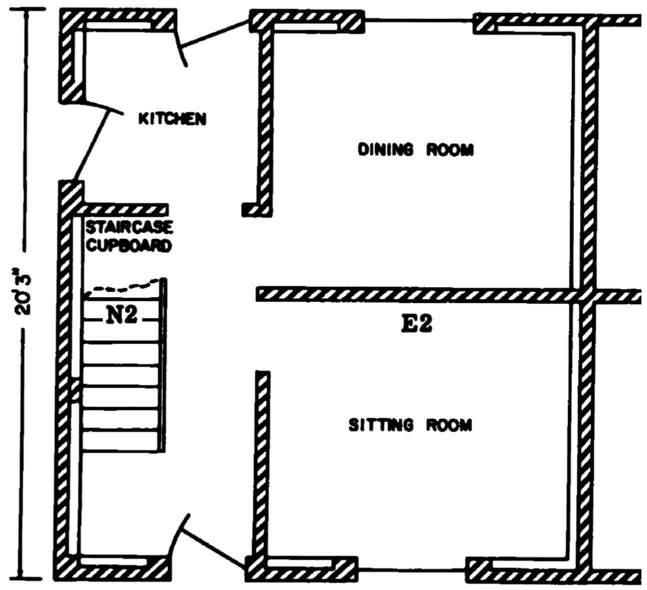
"A very much improved protection could be obtained by constructing a shelter core. This means a small, thick-walled shelter built preferably inside the fallout room itself, in which to spend the first critical hours when the radiation from fallout would be most dangerous."(1)

The full-scale experiments were carried out at the Civil Defense School at Falfield Park.(2)

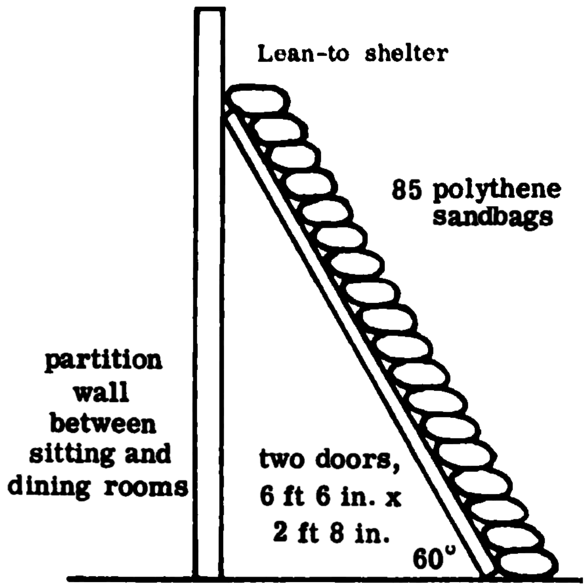
In the staircase construction, the shelter consisted of the cupboard under the stairs, sandbags being placed on treads above and at the sides.

A 93 curies cobalt-60 source was used.

1. Six sandbags per tread, and a double layer on the small top landing. 96 sandbags were used.
2. As (1), together with a 4-ft-high wall of sandbags along the external north wall. 160 sandbags were used.
3. As (2), together with 4-ft-high walls of sandbags along the kitchen/cupboard partition wall and along the passage partition. 220 sandbags were used.



sandbags 24 in. x 12 in. when empty; 16 in. x 9 in. x 4 in. when filled with 25 lb of sand.



floor area 21 sq ft.

9 in. brick walls The windows and doors were not blocked	Position	contribution r/hr/c/ft^2 Ground	Roof	Protective Factor
House only	E2	15.0	8.4	21
Lean-to	E2	10.4	2.4	39
Staircase cupboard:				
Stairs only sandbagged	N2	29.2	5.3	14
Stairs and outer wall sandbagged	N2	16.4	4.6	24
Stairs, outer wall, kitchen wall and corridor partition sandbagged	N2	8.8	1.8	47

1. Civil Defence Handbook No. 10, HMSO, 1963.
2. Perryman, A. D., Home Office Report CD/SA 117.

Foreword

If the country were ever faced with an immediate threat of nuclear war, a copy of this booklet would be distributed to every household as part of a public information campaign which would include announcements on television and radio and in the press. The booklet has been designed for free and general distribution in that event. It is being placed on sale now for those who wish to know what they would be advised to do at such a time.

May 1980

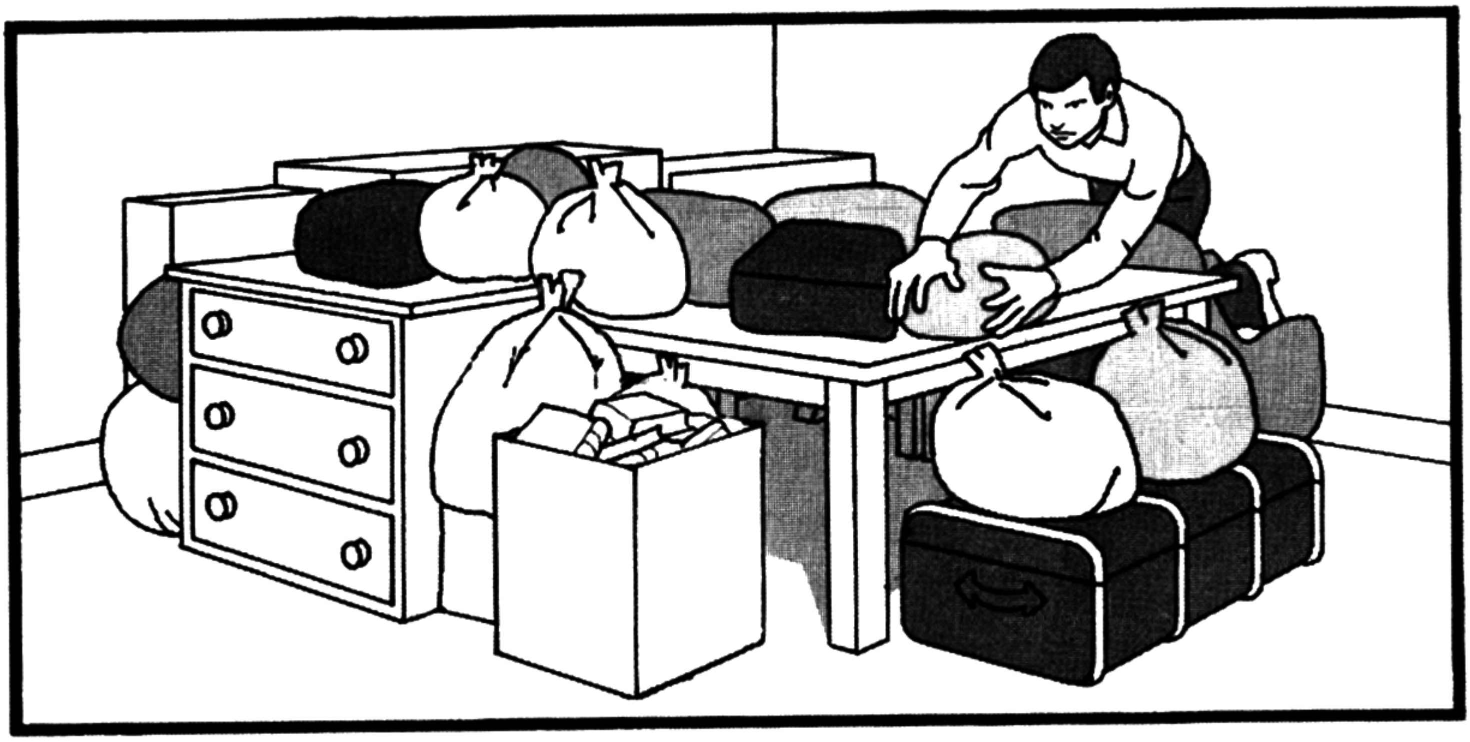
Protect and Survive
ISBN 0 11 3407289

If Britain is attacked by nuclear bombs or by missiles, we do not know what targets will be chosen or how severe the assault will be.

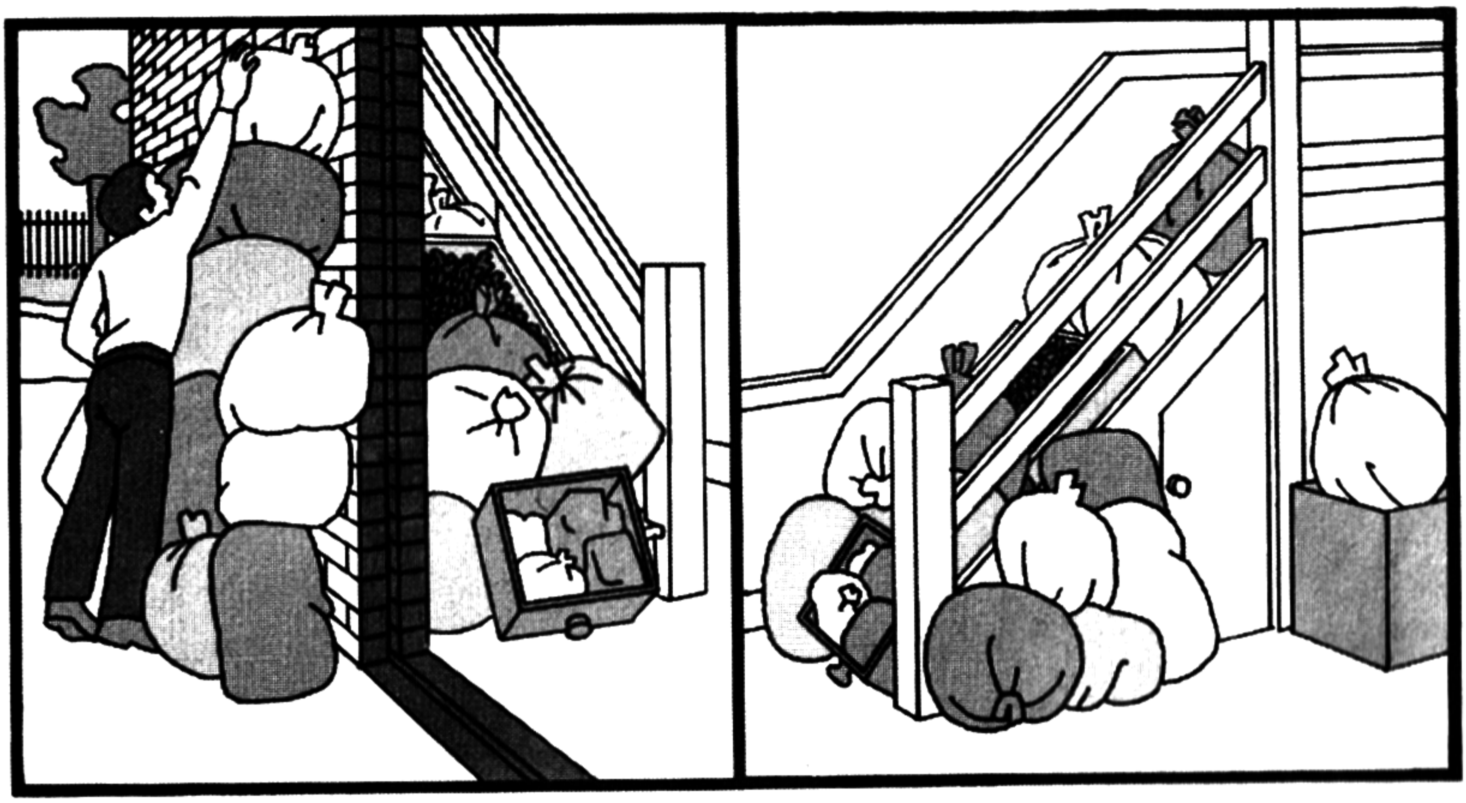
If nuclear weapons are used on a large scale, those of us living in the country areas might be exposed to as great a risk as those in the towns. The radioactive dust, falling where the wind blows it, will bring the most widespread dangers of all. No part of the United Kingdom can be considered safe from both the direct effects of the weapons and the resultant fall-out.

The dangers which you and your family will face in this situation can be reduced if you do as this booklet describes.

Use tables if they are large enough to provide you all with shelter. Surround them and cover them with heavy furniture filled with sand, earth, books or clothing.



Use the cupboard under the stairs if it is in your fall-out room. Put bags of earth or sand on the stairs and along the wall of the cupboard. If the stairs are on an outside wall, strengthen the wall outside in the same way to a height of six feet.



What to do after the Attack:

After a nuclear attack, there will be a short period before fall-out starts to descend. Use this time to do essential tasks. This is what you should do.

Do not smoke.

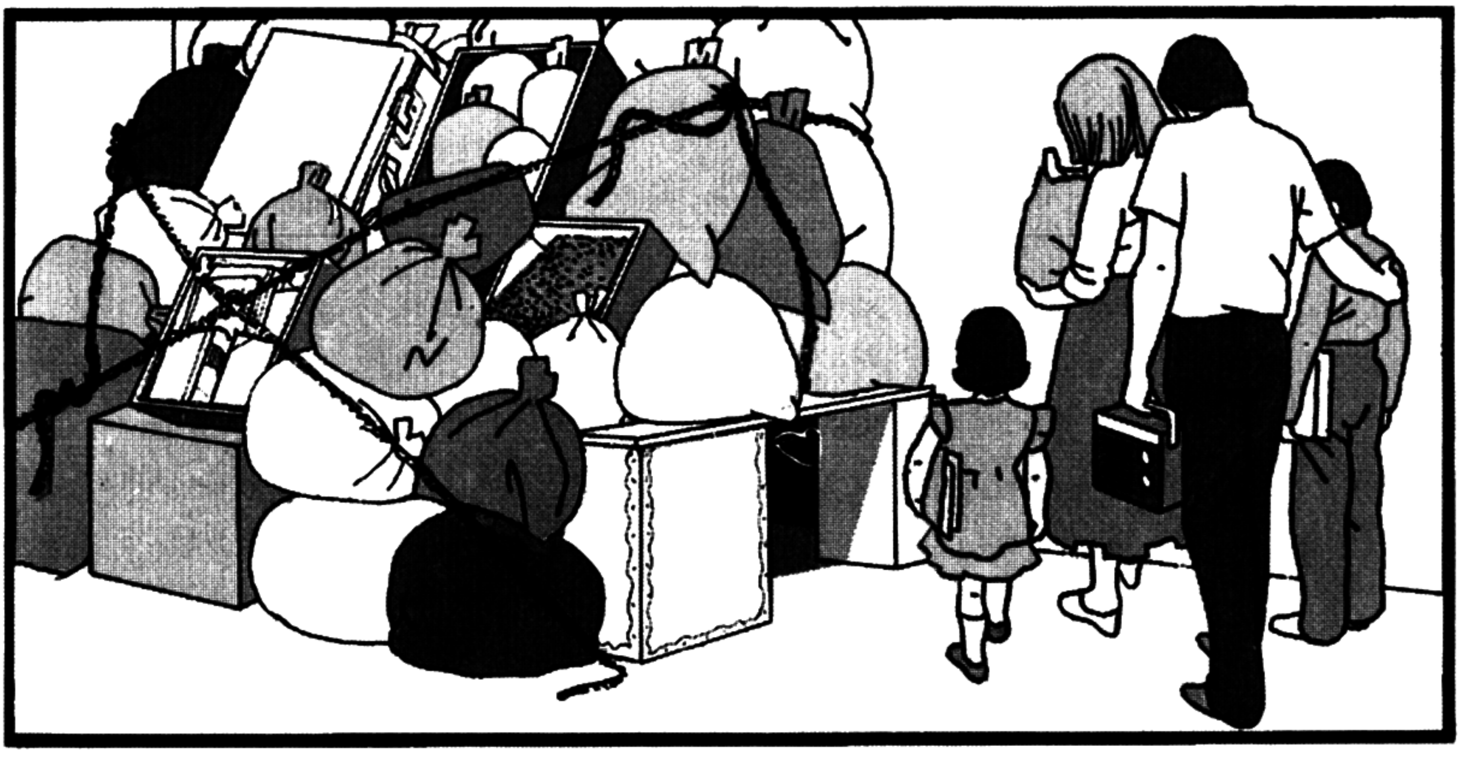
Check that gas, electricity and other fuel supplies and all pilot lights *are* turned off.

Go round the house and put out any small fires using mains water if you can.

If anyone's clothing catches fire, lay them on the floor and roll them in a blanket, rug or thick coat.

If there is structural damage from the attack you may have some time before a fall-out warning to do minor jobs to keep out the weather – using curtains or sheets to cover broken windows or holes.

If you are out of doors, take the nearest and best available cover as quickly as possible, wiping all the dust you can from your skin and clothing at the entrance to the building in which you shelter.



HOME OFFICE

SCOTTISH HOME DEPARTMENT

MANUAL OF CIVIL DEFENCE

Volume I

PAMPHLET No. 1

NUCLEAR WEAPONS

LONDON

HER MAJESTY'S STATIONERY OFFICE

1956

30 Research into the causes of fire in Hiroshima and Nagasaki, combined with a study of the secondary fire risk from the flying bomb damage in this country during the last war has shown that with nuclear attack the secondary fire risk is likely to be small compared with the primary risk of direct ignition by thermal radiation.

Fire precautions

31 Although the fire risk even from a nominal bomb is always serious, targets in this country, where the great majority of buildings are of brick, stone or concrete, are less vulnerable to fire than were those in Japan, where most of the buildings were of wood.

32 since the thermal radiation has no great penetrating power, any opaque screen, especially a white one, will keep it out:

33 Another obvious fire precaution is the removal of all readily combustible material from the direct path of any heat radiation that could possibly enter windows or other openings.

34 Both these precautions apply only to those windows and other openings that have a direct view of some part of the sky.

The probable fire situation in a British city

35 Japanese houses are constructed of wood and once they were set on fire they continued to burn even when knocked over. In this country only about 10 per cent. of all the material in the average house is combustible, and under conditions of complete collapse, where air would be almost entirely excluded, it is doubtful whether a fire could continue on any vigorous scale.

38 The Hiroshima bomb (but not the Nagasaki one) caused a fire storm. A fire storm occurred in Hamburg and possibly also in several other German cities as a result of accurate and very dense attacks with incendiary and high explosive bombs by the R.A.F. Information on the subject is limited, but it has been fairly well established that during these particular raids on Germany half the buildings in the target area were set on fire in about half an hour. In such circumstances it seems that nothing can prevent all the fires from joining together into one mass fire engulfing the whole area.

40 It seems unlikely from the evidence available that an initial density of fires equivalent to one in every other building would be started by a nuclear explosion over a British city. Studies have shown that a much smaller proportion of buildings than this would be exposed to thermal radiation and even then it is not certain that continuing fires would develop. Curtains may catch fire, but it does not necessarily follow that they will set light to the room; in the last war it was found that only one incendiary bomb out of every six that hit buildings started a continuing fire.

From a 10 megaton bomb, with its longer lasting thermal radiation (see paragraph 21), it takes about 20 calories per square centimetre to start fires because so much of the heat (spread out over the longer emission) is wasted by conduction into the interior of the combustible material and by convection and re-radiation whilst the

temperature of the surface is being raised to the ignition point. But the distance at which 20 calories per square centimetre can be produced is only 11 miles, so that the scaling factor for a 10 megaton airburst bomb is therefore 11 and not 22.

43 For a ground burst bomb, however, several other factors contribute to a further reduction in the fire range. Apart from an actual loss of heat by absorption into the ground and from the pronounced shielding effect of buildings, the debris from the crater tends to reduce the radiating temperature of the fireball and a greater proportion of the energy is consequently radiated in the infra red region of the spectrum—this proportion being more easily absorbed by the atmosphere.

44 An important point in relation to personal protection against the effects of hydrogen bomb explosions is that because the thermal radiation lasts so long there is more time for people who may be caught in the open, and who may be well beyond the range of serious danger from blast, to rush to cover and so escape some part of the exposure. For example, people in the open might receive second degree burns (blistering) on exposed skin at a range of 16 miles from a 10 megaton ground burst bomb (8×2—see paragraph 24). If, however, they could take cover in a few seconds they would escape this damage. Moreover, at this range the blast wave would not arrive for another minute and a half so that any effects due to the blast in the open (e.g. flying glass, etc.) could be completely avoided.

DOMESTIC NUCLEAR SHELTERS

TECHNICAL GUIDANCE

A HOME OFFICE GUIDE

Government bookshops

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Southey House, Wine Street, Bristol BS1 2BQ
258 Broad Street, Birmingham B1 2HE
80 Chichester Street, Belfast BT1 4JY

Government publications are also available through booksellers

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Printed in England for Her Majesty's Stationery Office by Hobbs the Printers of Southampton

ISBN 0 11 340777 7 (2462) Dd717557 C40 1/82 G381

Introduction

This manual of technical guidance on the design of domestic nuclear shelters has been prepared by a working group set up by the Emergency Services Division of the Home Office. The working group was asked to consider designs of nuclear shelters which could be made available to members of the public in the United Kingdom who might wish to purchase and install shelters for the use of themselves and their families.

The working group realised that the range of designs which it might produce would not be exhaustive. However, it was aware of the need to give technical guidance to professional engineers to assist them in producing reliable shelter designs. Thus the first three chapters of this book are written to give such guidance.

The other four chapters of the book give detailed designs of five shelters. These five cover a range of types which are applicable to different sorts of houses; they also cover a wide price range. These designs are not intended to be exhaustive, and as explained in the text, the working group is already giving attention to other designs, particularly those which might be incorporated into existing or new houses and also underground shelters of shapes other than box-like and using materials other than concrete. It is planned to publish details of this work at a later date.

The members of the working group are:

Mr J C Cotterill, *Chairman*	Scientific Advisory Branch, Home Office
Dr J R Stealey	Scientific Advisory Branch, Home Office
Mr A Lindfield	Scientific Advisory Branch, Home Office
Mr K A Day	F6 Division, Home Office
Mr R W T Haines, C Eng	Directorate of Works, Home Office
Mr H G S Banks, C Eng	Directorate of Works, Home Office
Mr M Connell, C Eng	Directorate of Civil Engineering Services Property Services Agency, Department of Environment
Mr S Bell, C Eng	Directorate of Civil Engineering Services Property Services Agency, Department of Environment
Mr S England, C Eng	Directorate of Mechanical and Electrical Engineering Services Property Services Agency, Department of Environment
Mr I Leys	Atomic Weapons Research Establishment, Ministry of Defence Foulness
Major I C T Ingall	HQ United Kingdom Land Forces Wilton, Wilts.
Mr R Million, *Secretary*	F6 Division, Home Office

Any enquiries concerning this manual should be addressed to the Home Office, F6 Division, and not to individual members of the working group.

To obtain some protection from the heat it is necessary to move out of the direct path of the rays from the fireball; any kind of shade will be of some value.

A fire-storm occurred only in an area of several square miles, heavily built up with buildings containing plenty of combustible material and where at least every other building in the area had been set alight. It is not considered that the initial density of fires, equivalent to one in every other building, would be caused by a nuclear explosion over a British city. Studies have shown that due to shielding, a much smaller proportion of buildings than this would be exposed to the heat flash. Moreover, the buildings in the centres of most British cities are now more fire-resistant and more widely spaced than they were 30 to 40 years ago. This low risk of fire-storms would be reduced still further by the control of small initial and secondary fires.

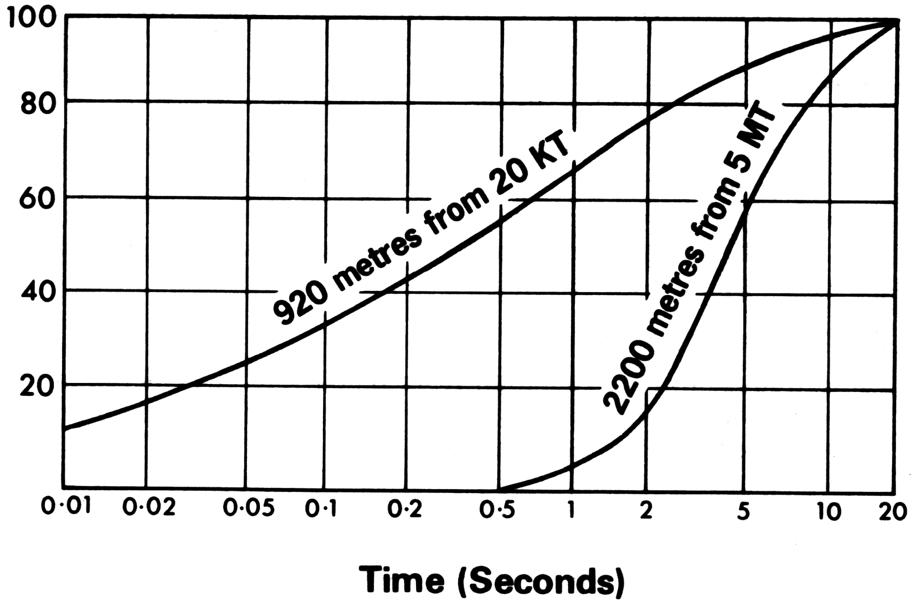
Fig. 8 ***Half-value thicknesses of shielding materials***

	Against INR mm	(inches)	Against fallout radiation mm	(inches)
Steel	38	(1.5)	18	(0.7)
Concrete	152	(6.0)	56	(2.2)
Earth	190	(7.5)	84	(3.3)
Water	330	(13.0)	122	(4.8)
Brickwork	157	(6.2)	71	(2.8)

The amount of scattering of initial gamma radiation depends upon a number of factors, but probably amounts to about 10 per cent of that in the main beam.

Fig. 9 gives the percentage of initial gamma radiation dose received as a function of time for 20 KT and 5 MT air bursts. It can be seen that in the former case about 65 per cent and in the latter case 5 per cent of the total initial gamma radiation dose is received during the first second. In the case of the higher yield weapon it can be seen that if some shelter could be obtained within one second of seeing the explosion flash, such as by falling prone behind some substantial object, it could make the difference between life and death. Such an action would also help to prevent the translational effect of the blast.

Fig. 9 ***Percentage of total initial gamma dose received***



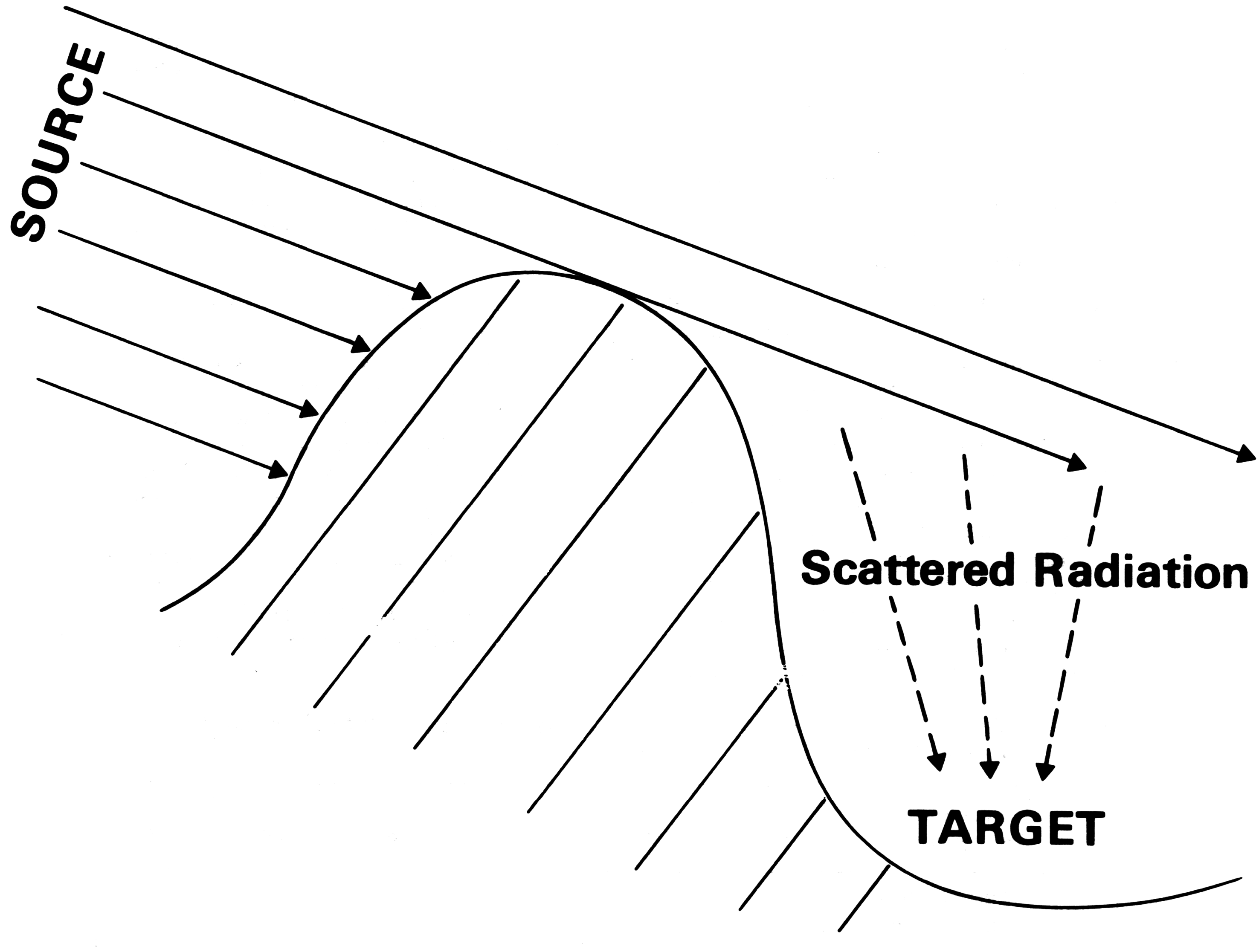


Fig. 10 ***Target exposed to scattered gamma radiation from a nuclear burst***

Further comments on protection against INR and fallout radiation

Fig. 12 gives a comparison of the protective factors against INR gamma, neutrons and fallout radiation of some typical buildings. The data has been taken from *Effects of Nuclear Weapons* and the choice has been made of those buildings which are reasonably comparable with structures in the UK. The wide range of values is due partly to uncertainty in the data (since some have been calculated and others derived from weapons trials) and partly to the fact that protection to some extent is determined by the position in the building where the protective factor is measured.

Fig. 12 ***Protective factors of various buildings against initial gamma, neutron and fallout gamma radiation***

Structure	Initial gamma	Neutrons	Fallout gamma
1 metre underground	250–500	100–500	5000
Shelter partly above ground: with 600 mm earth 900 mm earth	 15–35 50–150	 12–50 20–100	 50–200 200–1000

Summary of effects of nuclear weapons

From this brief review of the effects of nuclear weapons we can list the order of events from the detonation of a weapon. These are:

(a) Light and heat flash – immediate, and lasting some seconds.

(c) Blast wave – following from about a half second to several seconds after the light and heat flash.

(d) Fires – these may have been ignited by the heat flash

(e) Fallout – about one half hour to several hours after burst.

Considerations arising from the probable attack pattern

In section 1.1.1 reference was made to the fact that an expected attack pattern on the United Kingdom might use 200 megatons on about 80 targets. If we now make an assumption that this attack would be in the form of 100 weapons of 1 MT airbursts and 100 weapons of 1 MT groundbursts we can use the information given in Fig. 6 to indicate the probability of areas being subject to various effects.

On this assumption, we should find that about 2.2 per cent of the land area of the UK would be subject to overpressures in the 'A' ring of 77 kPa (11 psi) and above about 1.8 per cent would be subject to overpressures of between 42 and 77 kPa (6-11 psi) in the 'B' ring and about 10 per cent of the land area would be subject to overpressures of between 10 and 42 kPa (1.5 to 6 psi). The rest of the land area, about 85 per cent, would be subject to blast in the D ring of 5 to 10 kPa (0.75 to 1.5 psi) or to no blast at all. Blast effects in the D ring will cause minor damage to buildings and no lethalities.

SEPTEMBER 1964

HOME OFFICE

CD/SA 121

SCIENTIFIC ADVISER'S BRANCH

IGNITION AND FIRE SPREAD IN URBAN AREAS FOLLOWING A NUCLEAR ATTACK

G. R. Stanbury

INITIAL FIRE INCIDENCE

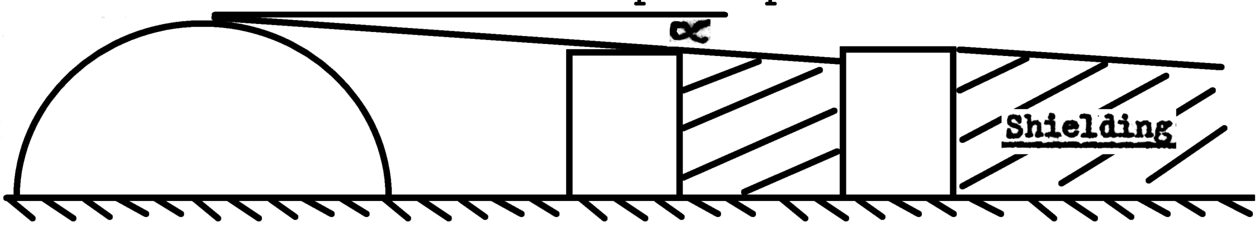
For a 1 MT groundburst bomb the height of the top of the fireball above ground is about 0.72 miles. Because this distance is large compared with the height of most buildings, the exposed upper floors do actually see a large part of the fireball and not just the top of it, but in assuming that the radiation is just as intense from the top as from the middle we were overestimating the fire risk.

On the above basis the following table gives the number of exposed upper floors (to the nearest ½ floor) for a range of distances from the explosion and a range of street widths.

Effect of Shielding: Estimation of the number of exposed floors

Assuming that buildings on opposite sides of a street which is receiving heat radiation from a direction perpendicular to its length are of the same height

Thermal pulse precedes the blast wave



Distance from explosion miles	Angle of arrival α^{o}	tan α	Width of street (units of 10 ft.)						
			2	3	4	5	6	7	8
1	35	.72	1.5	2	3	3.5	4.5	5	6
1½	26	.48	1	1.5	2	2.5	3	3.5	4
2	20	.36	.5	1	1.5	2	2	2.5	3
3	13½	.24	.5	.5	1	1	1.5	1.5	2
4	10	.18	.5	.5	.5	1	1	1.5	1.5
5	8	.15	.5	.5	.5	.5	1	1	1

we take the average depth of a floor to be 10 ft.

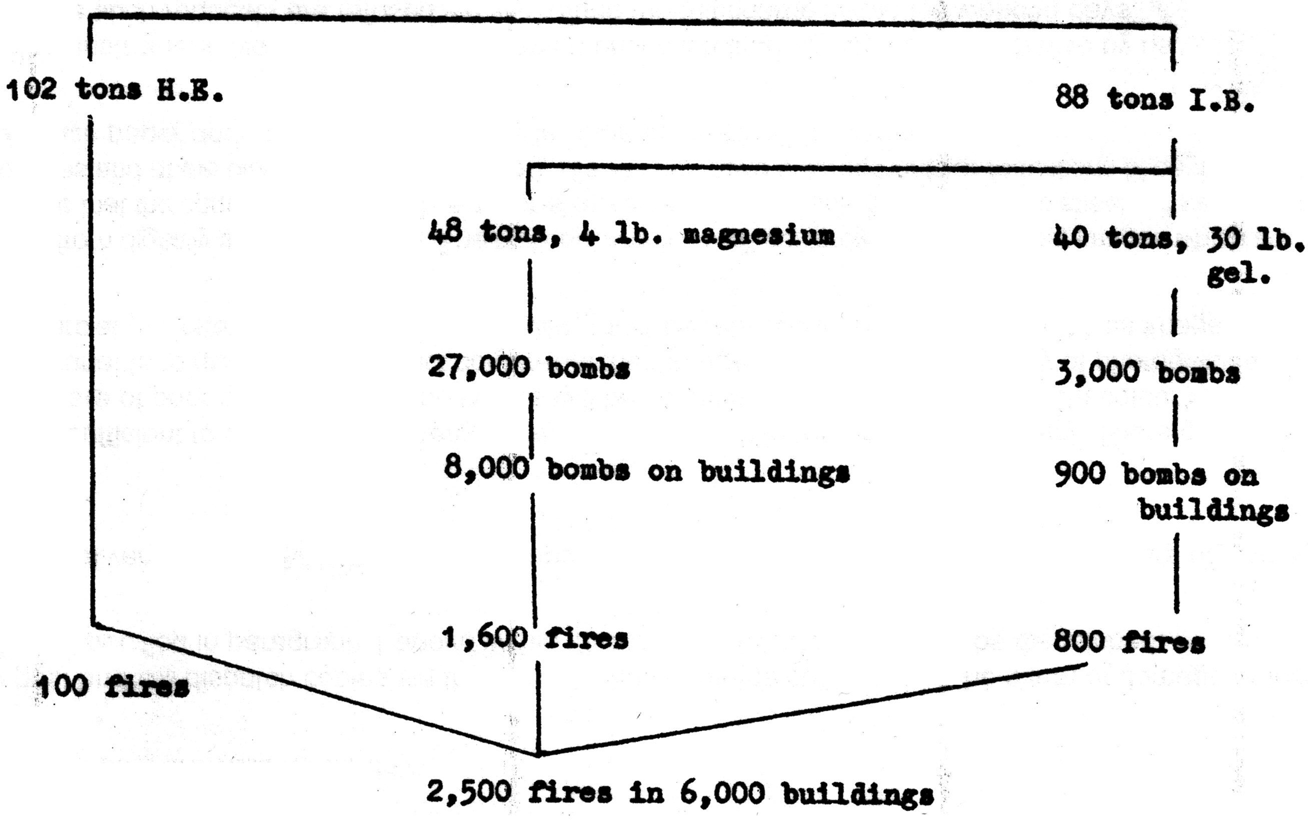
Angle between heat flash and street (degrees)	90-75	75-60	60-45	45-30	30-15	15-0
Proportion of heat flash entering windows %	99	92.5	80	60	40	14

SPREAD OF FIRE

From last war experience of mass fire raids in Germany it was concluded that the overall spread factor was about 2; i.e. about twice as many buildings were destroyed by fire as were actually set alight by incendiary bombs

Number of fires started per square mile in the fire-storm raid on Hamburg, 27th/28th July, 1943

Bombs dropped



However, the important thing to note is that the total number of fires started in each square mile (2,500) was nearly half that of the total number of buildings; in other words, almost every other building was set on fire during the raid itself. When this happened no fire-fighting organisation, however efficient could hope to prevent the fires from joining together and engulfing the whole area.

When the figure of 1 in 2 for the German fire storms is compared with the figures for initial fire incidence of $\sim$ 1 in 15 to 30 obtained in the Birmingham and Liverpool studies it can only be concluded that a nuclear explosion could not possibly produce a fire storm.

Fire situation from 1,499 fly bombs in the built-up part of the London Region

WWII V1 high explosives (1 ton TNT warhead) (cruise missiles)

Where dropped	Number of fly bombs	Fly Bombs Caused				
		No fire	Small fire	Medium fire	Serious fire	Major fire
City	119 ~~199~~	47	49	17	4	2
West-End	33	8	22	2	-	1
Closed Residential	430	207	203	20	-	-
Open Residential	804	478	296	28	2	-
Docks	113	64	39	8	1	1
Grand Totals	1,499	804	609	75	7	4

Discussion of results

Two important points emerge from a study of these results:-

(i) The small proportion of fly bombs - less than 20% - which started fires of any greater category than "small" even in the most heavily built-up areas; and

(ii) The large proportion which started no fires at all even in the most heavily built-up areas.

All these fly bombs fell in the summer months of 1944 which were unusually dry. In winter in this country in residential areas there are many open fires which may provide extra sources of ignition. The domestic occupancy is a low fire risk however, and as the proportion of such property in the important City and West End areas is small this should not introduce any serious error. Moreover, in winter, the high atmospheric humidity and the correspondingly high moisture content of timber would tend to retard or even prevent the growth of fire.

In order to determine how many fly bombs are equivalent to one nominal atomic bomb one method is to compare the areas over which a given category of house damage is produced by each. If we do this for a $\frac{3}{8}$th mile air burst as at Hiroshima, the result is that 1 atomic bomb does as much damage as about 1,200 fly bombs.

This in itself is not a serious fire situation and it is doubtful whether it could ever give rise to a fire storm. In Hamburg 2,500 fires were started per square mile by a bomb density (combined H.E. and I.B.) of 2oo tons per square mile, and for the area of destruction produced by an atomic bomb this would correspond to a total of about 10,000 fires.

UCRL-TR-231593

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Thermal Radiation from Nuclear Detonations in Urban Environments

R. E. Marrs, W. C. Moss, B. Whitlock

June 7, 2007

An obvious next step (left for future work) would be a calculation of burn injuries and fires. Even without shadowing, the location of most of the urban population within buildings causes a substantial reduction in casualties compared to the unshielded estimates. Other investigators have estimated that the reduction in burn injuries may be greater than 90% due to shadowing and the indoor location of most of the population [6].

We have shown that common estimates of weapon effects that calculate a "radius" for thermal radiation are clearly misleading for surface bursts in urban environments. In many cases only a few unshadowed vertical surfaces, a small fraction of the area within a thermal damage radius, receive the expected heat flux.

In future work, our code could be extended to tally the total surface area receiving various amounts of heat, and to account for reflected radiation.

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The Effects of

Nuclear Weapons

SAMUEL GLASSTONE

Editor

Revised Edition

Reprinted February 1964

Prepared by the

UNITED STATES DEPARTMENT OF DEFENSE

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UNITED STATES ATOMIC ENERGY COMMISSION

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Foreword

This book is a revision of "The Effects of Nuclear Weapons" which was issued in 1957. It was prepared by the Defense Atomic Support Agency of the Department of Defense in coordination with other cognizant governmental agencies and was published by the U.S. Atomic Energy Commission. Although the complex nature of nuclear weapons effects does not always allow exact evaluation, the conclusions reached herein represent the combined judgment of a number of the most competent scientists working on the problem.

There is a need for widespread public understanding of the best information available on the effects of nuclear weapons. The purpose of this book is to present as accurately as possible, within the limits of national security, a comprehensive summary of this information.

Secretary of Defense

Chairman
Atomic Energy Commission

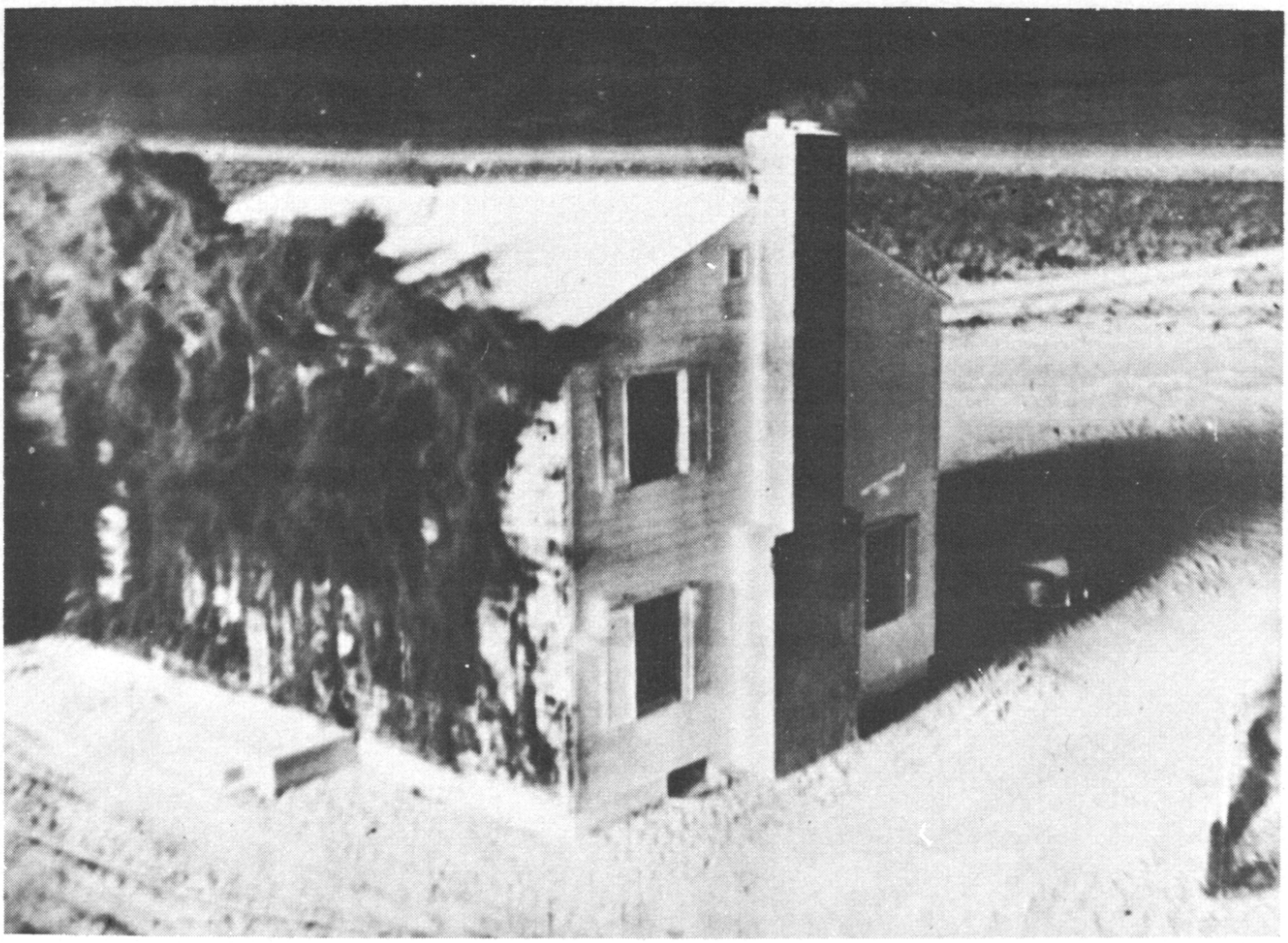


Figure 7.33a. Thermal effects on wood-frame house 1 second after explosion (about 25 cal/sq cm).

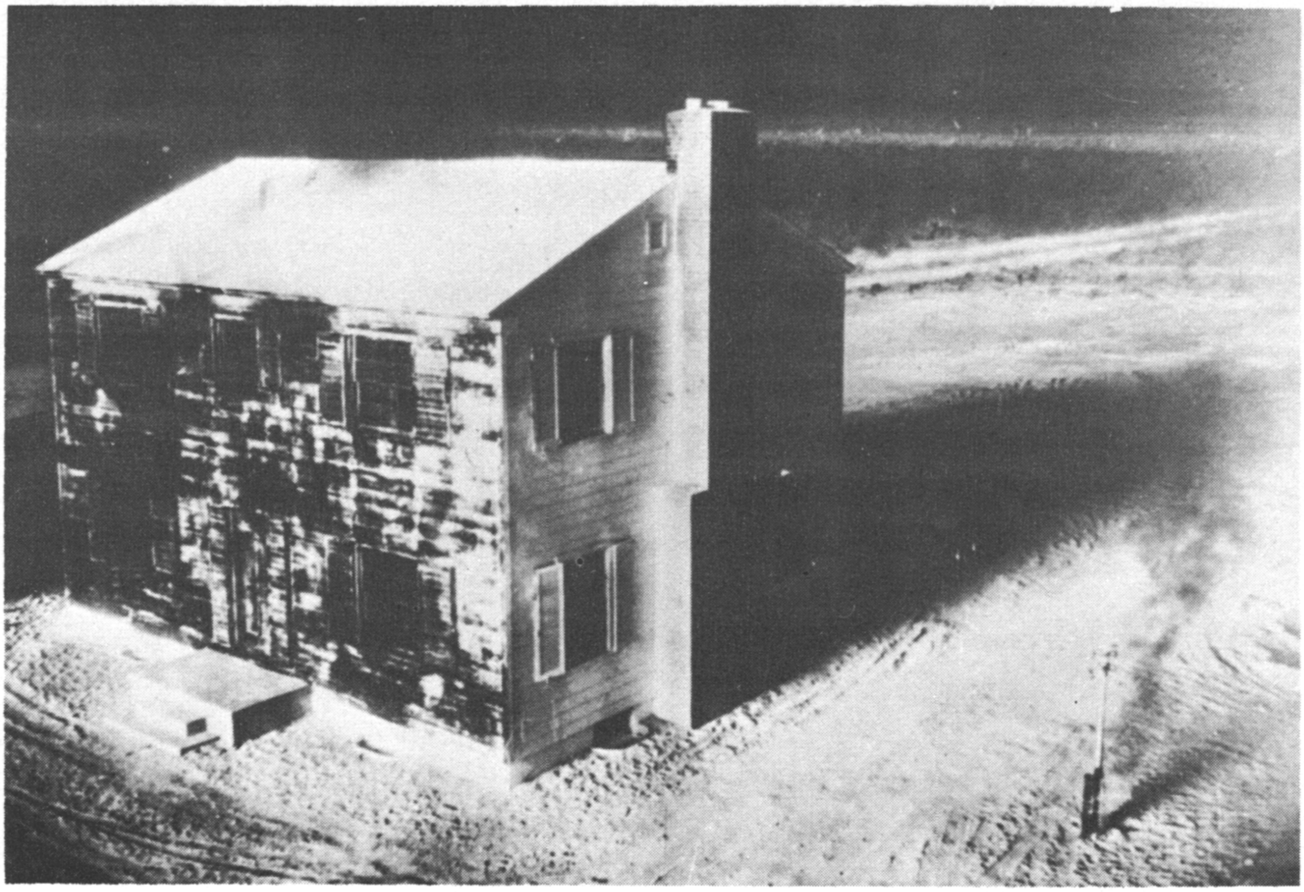


Figure 7.33b. Thermal effects on wood-frame house about ¾ second later.

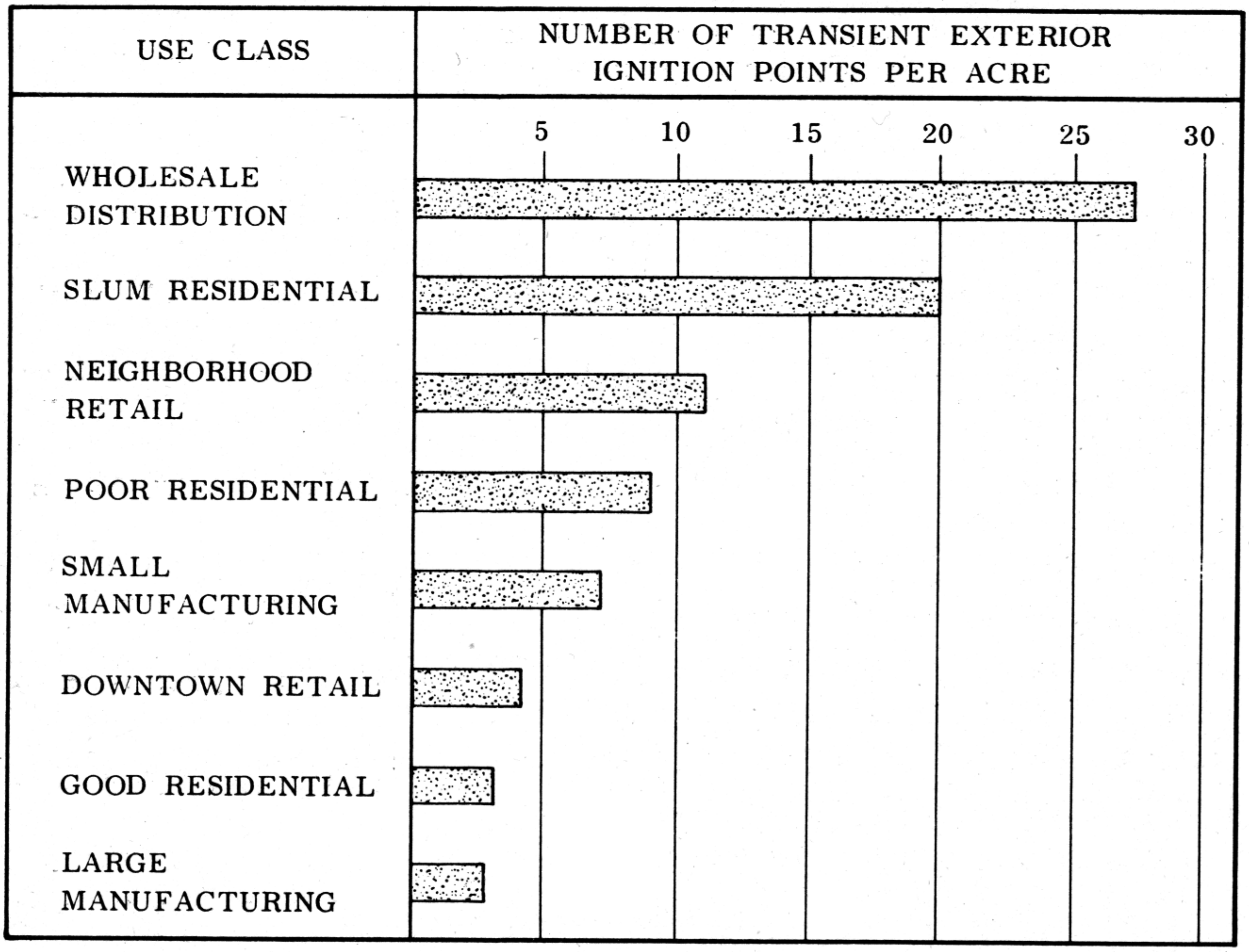


Figure 7.55. Frequency of exterior ignition points for various areas in a city

the formation of a significant fire, capable of spreading, will require appreciable quantities of combustible material close by, and this may not always be available.

7.57 The fact that accumulations of ignitable trash close to a wooden structure represent a real fire hazard was demonstrated at the nuclear tests carried out in Nevada in 1953. In these tests, three miniature wooden houses, each having a yard enclosed with a wooden fence, were exposed to 12 calories per square centimeter of thermal radiation. One house, at the left of Fig. 7.57, had weathered siding showing considerable decay, but the yard was free from trash. The next house also had a clean yard and in addition, the exterior siding was well maintained and painted. In the third house, at the right of the photograph, the siding, which was poorly maintained, was weathered, and the yard was littered with trash.

7.58 The state of the three houses after the explosion is seen in Fig. 7.58. The third house, at the right, soon burst into flame and was burned to the ground. The first house, on the left, did ignite but it did not burst into flame for 15 minutes. The well maintained house in the center with the clean yard suffered scorching only. It is of interest to recall that the wood of a newly erected white-painted

Figure 7.57. Wooden test houses before exposure to a nuclear explosion, Nevada Test Site.

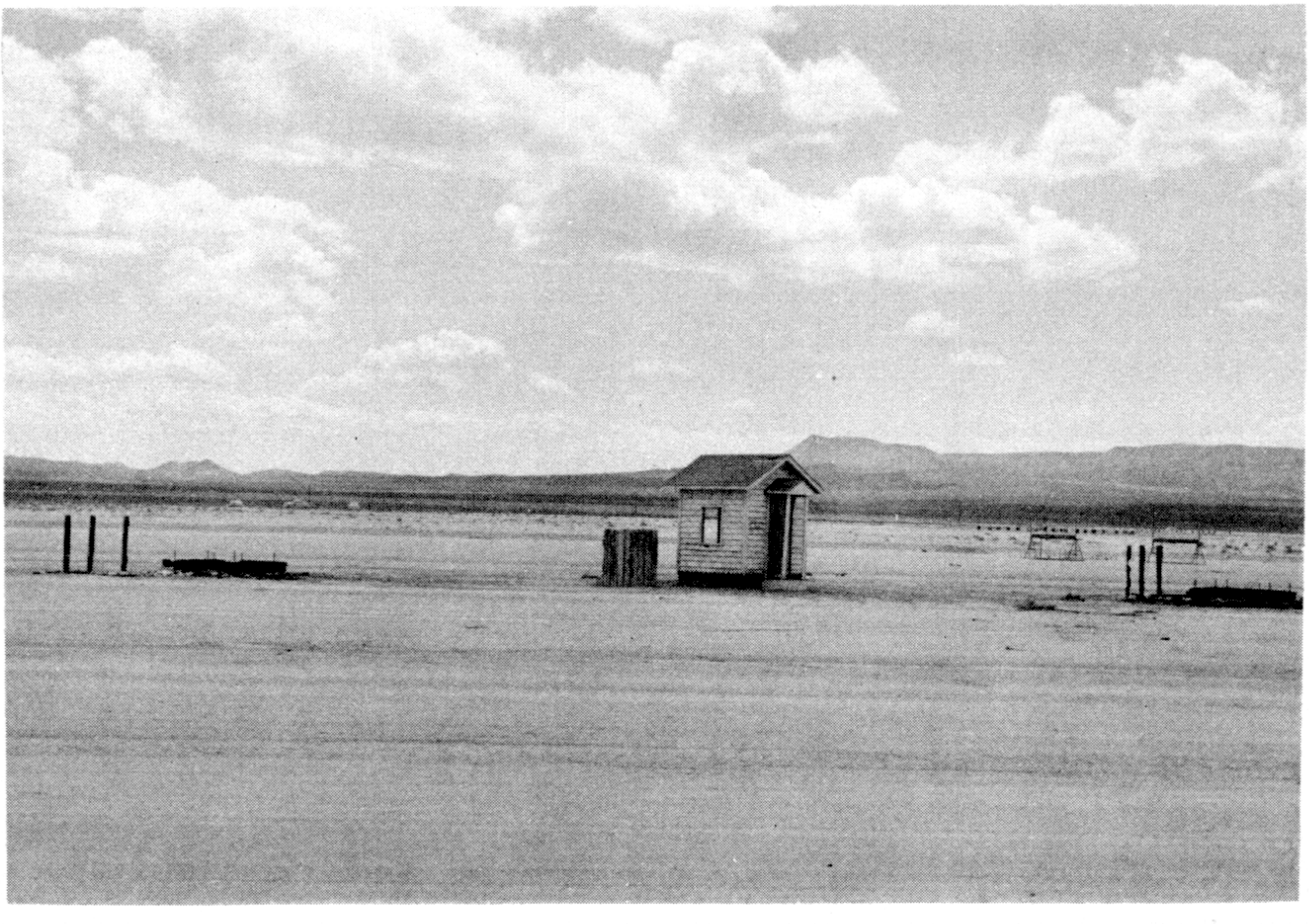


Figure 7.58. Wooden test houses after exposure to a nuclear explosion.

house exposed to about 25 calories per square centimeter was badly charred but did not ignite (see Fig. 7.33b).

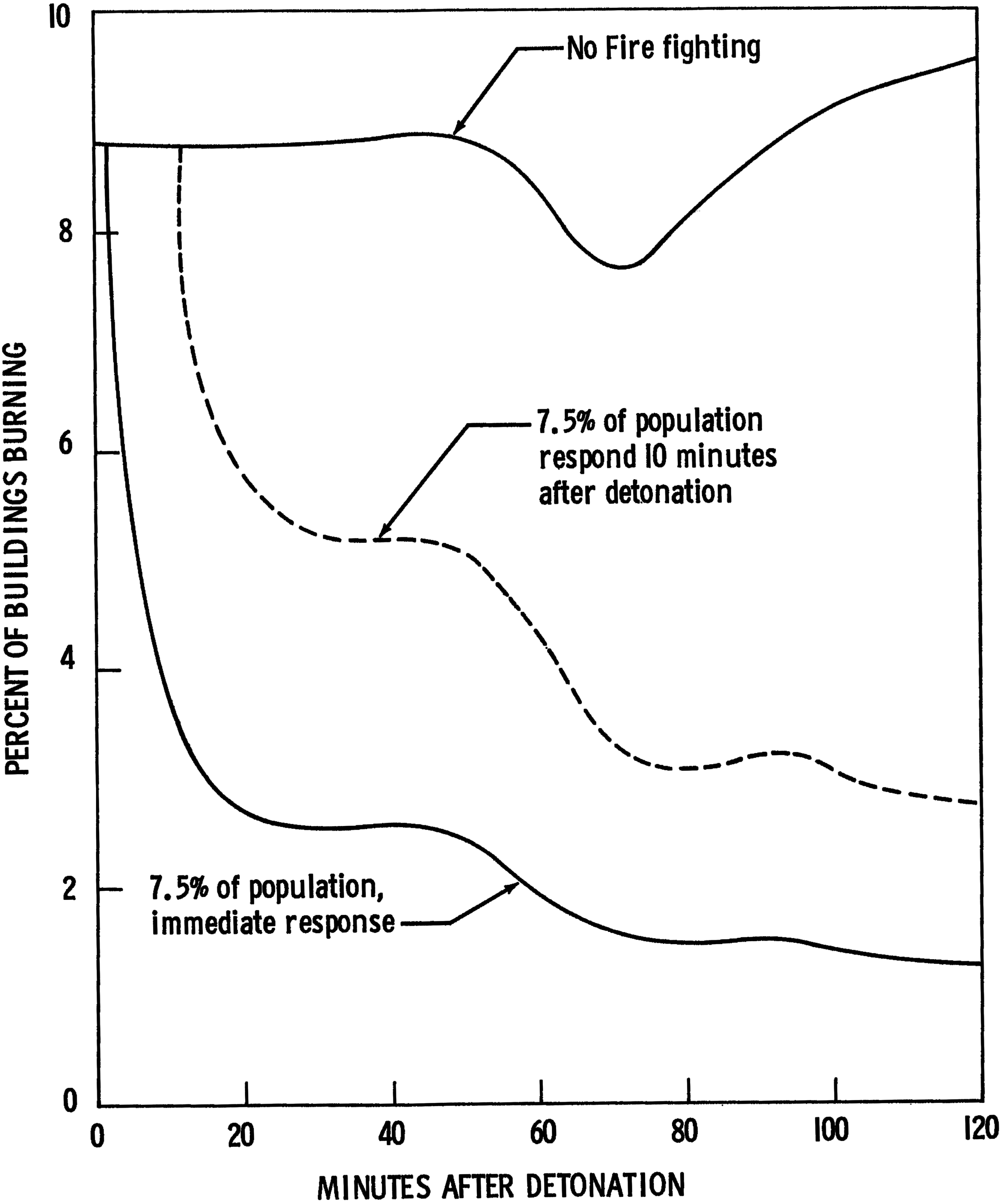
7.59 The value of fire-resistive furnishing in decreasing the number of ignition points was also demonstrated in the tests. Two identical, sturdily constructed houses, each having a window 4 feet by 6 feet facing the point of burst, were erected where the thermal radiation exposure was 17 calories per square centimeter. One of the houses contained rayon drapery, cotton rugs, and clothing, and, as was expected, it burst into flame immediately after the explosion and burned completely. In the other house, the draperies were of vinyl plastic, and rugs and clothing were made of wool. Although much ignition occurred, the recovery party, entering an hour after the explosion, was able to extinguish the fires.

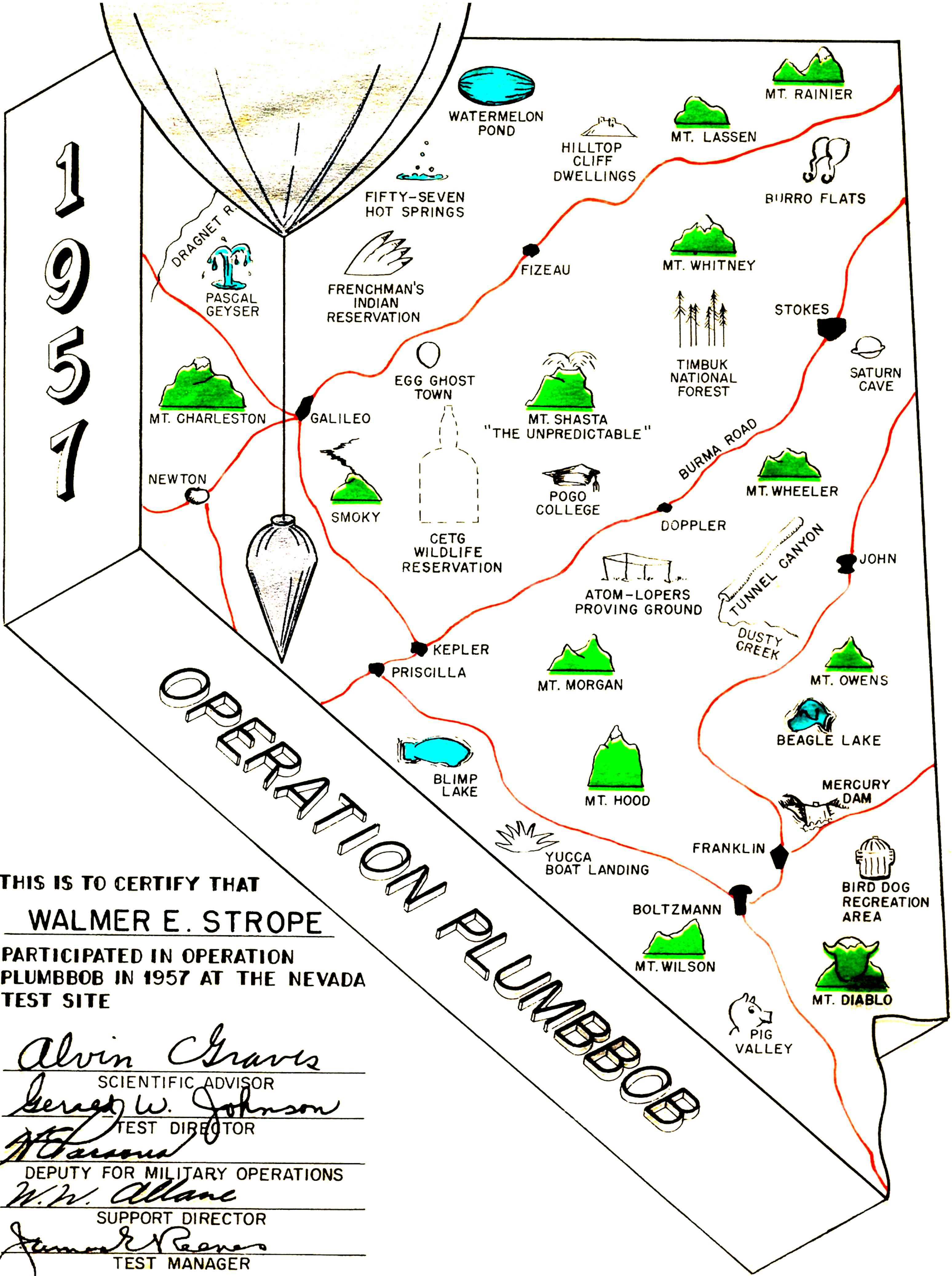
7.76 It should be noted that the fire storm is by no means a special characteristic of nuclear weapons. Similar fire storms have been reported as accompanying large forest fires in the United States, and especially after incendiary bomb attacks in both Germany and Japan during World War II. The high winds are produced largely by the updraft of the heated air over an extensive burning area. They are thus the equivalent, on a very large scale, of the draft of a chimney under which a fire is burning. Because of limited experience, the conditions for the development of fire storms in cities are not well known. It appears, however, that some, although not necessarily all, of the essential requirements are the following: (1) thousands of nearly simultaneous ignitions over an area of at least a square mile, (2) heavy building density, e.g., more than 20 percent of the area is covered by buildings, and (3) little or no ground wind. Based on these criteria, only certain sections—usually the older and slum areas—of a very few cities in the United States would be susceptible to fire storm development.

12.35. The major part of the thermal radiation travels in straight lines, and so any opaque object interposed between the fireball and the exposed skin will give some protection. This is true even if the object is subsequently destroyed by the blast, since the main thermal radiation pulse is over before the arrival of the blast wave.

12.36 At the first indication of a nuclear explosion, by a sudden increase in the general illumination, a person inside a building should immediately fall prone, as described in § 12.30, and, if possible, crawl behind or beneath a table or desk or to a planned vantage point. Even if this action is not taken soon enough to reduce the thermal radiation exposure greatly, it will minimize the displacement effect of the blast wave and provide a partial shield against splintered glass and other flying debris. An individual caught in the open should fall prone to the ground in the same way, while making an effort to shade exposed parts of the body. Getting behind a tree, building, fence, ditch, bank, or any structure which prevents a direct line of sight between the person and the fireball, if possible, will give a major degree of protection. If no substantial object is at hand, the clothed parts of the body should be used to shield parts which are exposed.

Takata, A.N., **Mathematical Modeling of Fire Detenses, IITRI, March 1970, AD 705 388.**





THIS IS TO CERTIFY THAT

WALMER E. STROPE

PARTICIPATED IN OPERATION PLUMBBOB IN 1957 AT THE NEVADA TEST SITE

Alvin Graves
SCIENTIFIC ADVISOR

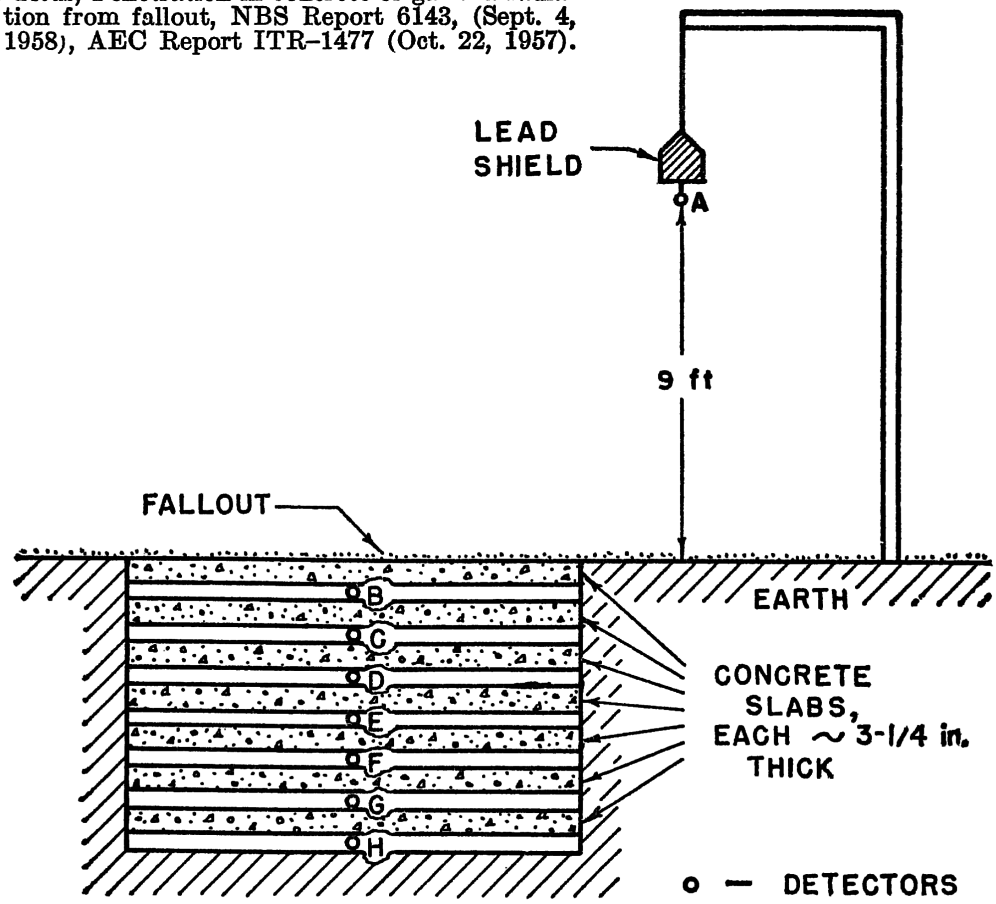
Gerald W. Johnson
TEST DIRECTOR

W. Parsons
DEPUTY FOR MILITARY OPERATIONS

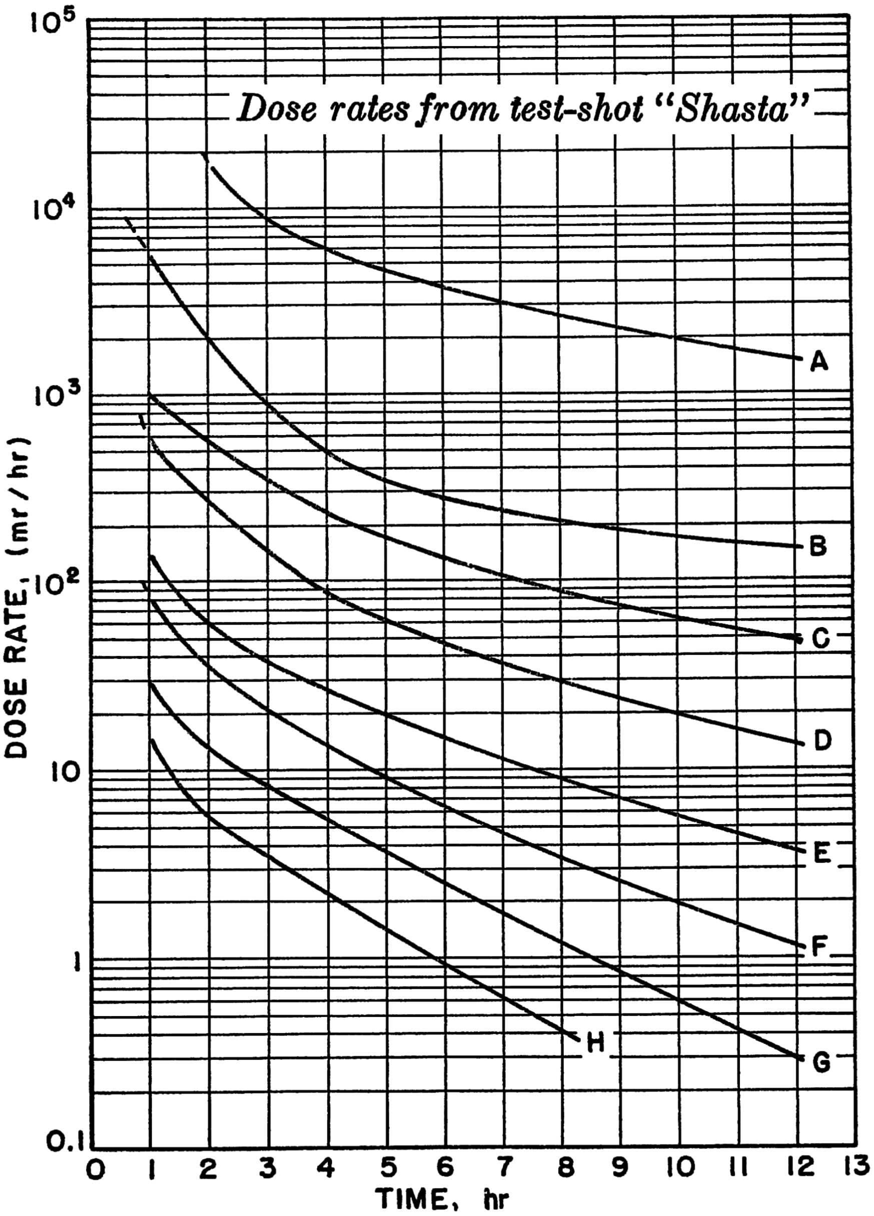
W. W. Allane
SUPPORT DIRECTOR

James E. Reeves
TEST MANAGER

F. Titus, Penetration in concrete of gamma radiation from fallout, NBS Report 6143, (Sept. 4, 1958), AEC Report ITR–1477 (Oct. 22, 1957).



The lead shield prevents fallout material from settling directly on detector "A," while at the same time shielding against the intercepted material



CIVIL DEFENCE

why we need it

Message from the Home Secretary and the Secretary of State for Scotland

For over 30 years our country, with our allies, has sought to avoid war by deterring potential aggressors. Some disagree as to the means we should use. But whatever view we take, we should surely all recognise the need – and indeed the duty – to protect our civil population if an attack were to be made upon us; and therefore to prepare accordingly.

The Government is determined that United Kingdom civil defence shall go ahead. The function of civil defence is not to encourage war, or to put an acceptable face on it. It is to adapt ourselves to the reality that we at present must live with, and to prepare ourselves so that we could alleviate the suffering which war would cause if it came.

Even the strongest supporter of unilateral disarmament can consistently give equal support to civil defence, since its purpose and effect are essentially humane.

George Younger.

Why bother with civil defence?

Why bother with wearing a seat belt in a car? Because a seat belt is reckoned to lessen the chance of serious injury in a crash. The same applies to civil defence in peacetime.

War would be horrific. Everyone knows the kind of devastation and suffering it could cause. But while war is a possibility – however slight – it is right to take measures to help the victims of an attack, whether nuclear or 'conventional'.

But isn't it a waste of money in these days of nuclear weapons and the dreadful prospects of destruction?

No. It is money well spent if it shows people how they can safeguard themselves and their families.

But surely there is no real protection against a nuclear attack?

Millions of lives could be saved, by safeguards against radiation especially. But civil defence is not just protection against a nuclear attack. It is protection against *any* sort of attack. NATO experts reckon that any war involving the UK is likely at least to start with non-nuclear weapons. Indeed, while no war is likely so long as we maintain a credible deterrent, the likelihood of a nuclear war is less than that of a 'conventional' one.

But doesn't civil defence get people more war-minded, thus increasing the risk of conflict?

That is like saying people who wear seat belts are expecting to have more crashes than those who do not. Taking civil defence seriously means seeking to save lives in the catastrophe of an attack on our country.

To Sum Up

The case for civil defence stands regardless of whether a nuclear deterrent is necessary or not. Radioactive fallout is no respecter of neutrality. Even if the UK were not itself at war, we would be as powerless to prevent fallout from a nuclear explosion crossing the sea as was King Canute to stop the tide. This is why countries with a long tradition of neutrality (such as Switzerland and Sweden) are foremost in their civil defence precautions.

Civil defence is common sense

Further information:

Nuclear Weapons
ISBN 0 11 34055 X — HMSO £3.50 (net)

Protect and Survive
ISBN 0 11 3407289 — HMSO 50p (net)

Domestic Nuclear Shelters
ISBN 0 11 3407378 — HMSO 50p (net)

Domestic Nuclear Shelters – Technical Guidance
ISBN 0 11 34073786 — HMSO £5.50 (net)

HOME OFFICE

SCOTTISH HOME DEPARTMENT

MANUAL OF CIVIL DEFENCE

Volume I

PAMPHLET No. 1

NUCLEAR WEAPONS

LONDON

HER MAJESTY'S STATIONERY OFFICE

1956

Practical protection

88 Large buildings with a number of storeys, especially if they are of heavy construction, provide much better protection than small single-storey structures (see Figure 4). Houses in terraces likewise provide much better protection than isolated houses because of the shielding effect of neighbouring houses.

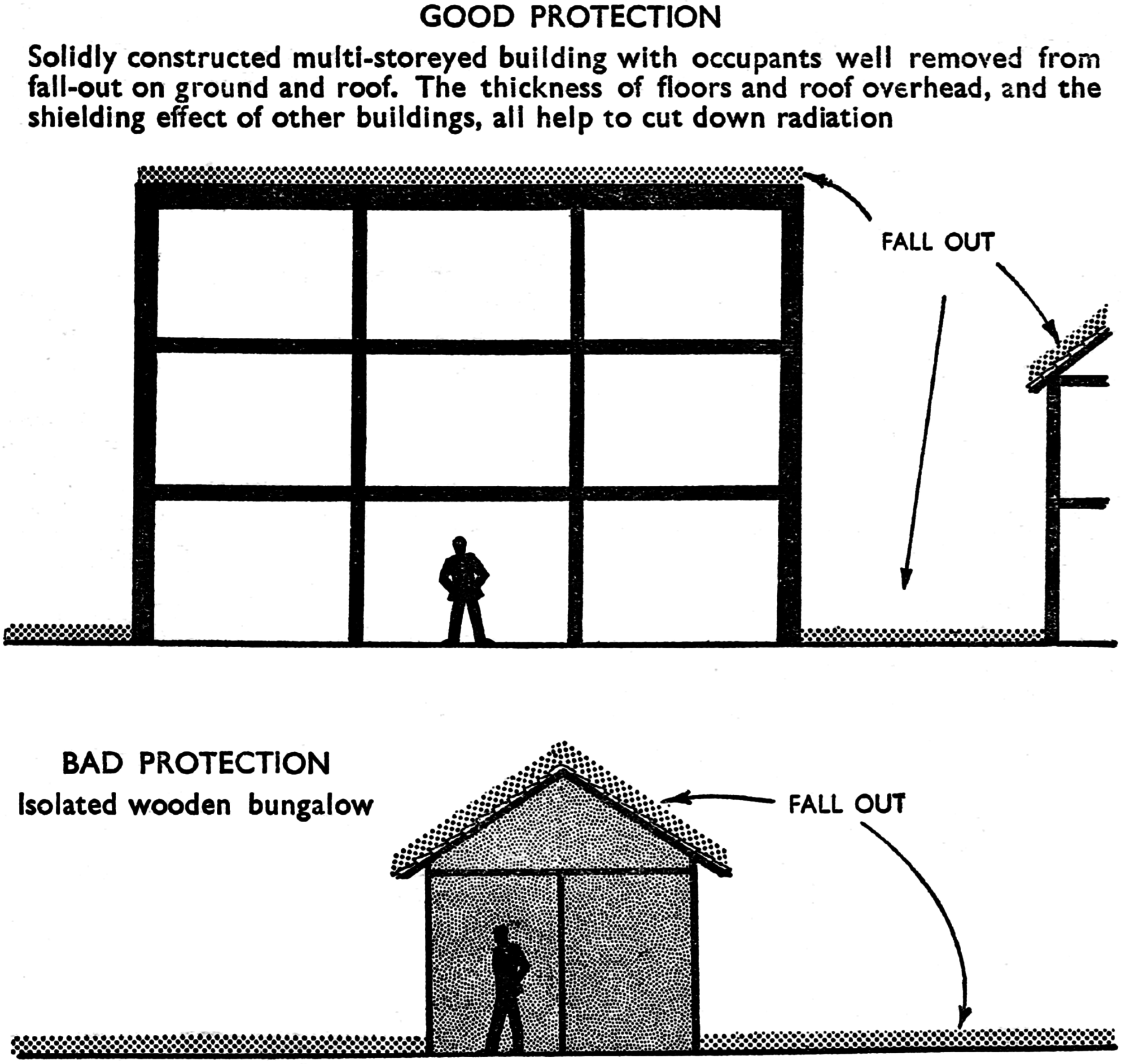


FIGURE 4
Examples of good and bad protection afforded by buildings against fall-out.

89 It is estimated that the protection factor (the factor by which the outside dose has to be divided to get the inside dose) of a ground floor room in a two-storey house ranges from 10 to about 50, depending on wall thickness and the shielding afforded by neighbouring buildings. The corresponding figures for bungalows are about 10–20, and for three-storey houses about 15–100. An average two-storey brick house in a built-up area gives a factor of 40, but basements, where the radiation from outside the house is attenuated by a very great thickness of earth, have protection factors ranging up to 200–300. A slit trench with even a light cover of boards or corrugated iron without earth overhead gives a factor of 7, and if 1 ft. of earth cover is added the

factor rises to 100. If the trench can be covered with 2 or 3 feet of earth then a factor of more than 200–300 can be obtained (see Figure 5).

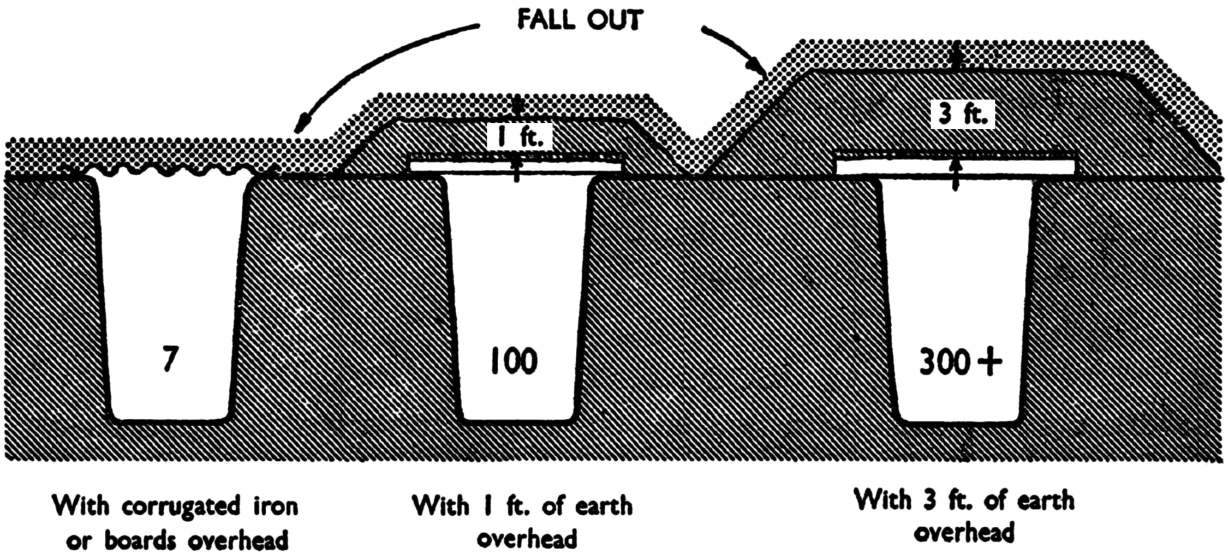


FIGURE 5
Protection factors in slit trenches (the factor by which the outside dose is divided to get the inside dose).

Choosing a refuge room

90 In choosing a refuge room in a house one would select a room with a minimum of outside walls and make every effort to improve the protection of such outside walls as there were. In particular the windows would have to be blocked up, e.g. with sandbags. Where possible, boxes of earth could be placed round an outside wall to provide additional protection, and heavy furniture (pianos, bookcases etc.) along the inside of the wall would also help. A cellar would be ideal. Where the ground floor of the house consists of boards and timber joists carried on sleeper walls it may be possible to combine the high protection of the slit trench with some of the comforts of the refuge room by constructing a trench under the floor.
Once a trap door had been cut in the floor boards and joists and the trench had been dug, there would be no further interference with the peace-time use of the room.

Estimated under-cover doses in the fall-out area

91 Taking an average protective factor of 40 for a two-storey house in a built-up area, the doses accumulated in 36 hours for the ranges referred to in the U.S. Atomic Energy Commission Report (paragraph 84) would have been:—

190 miles downwind	$7\frac{1}{2}$r	15 Megatons
160 ,, ,,	$12\frac{1}{2}$r	Bravo 1954
140 ,, ,,	20r	

which are all well below the lowest figure of 25r referred to in Table 1. At closer ranges along the axis of the fall-out, the doses accumulated in 36 hours would have been much higher, but over most of the contaminated area—with this standard of protection—the majority of those affected would have been saved from death, and even from sickness, by taking cover continuously for the first 36 hours.

5. **Radiation sickness**

Assume dose incurred in a single shift (3–4 hours) by the "average" man, over the whole body:—

25 roentgens		—No obvious harm.
100 ,,		—Some nausea and vomiting.
500 ,,		—Lethal to about 50 per cent. people (death up to 6 weeks later).
800 ,,	or more	—Lethal to all (death up to 6 weeks later).

Note: If dose spread uniformly over 2–3 days, then 60 roentgens could be incurred with no more effect than 25 roentgens in a single exposure of 3–4 hours.

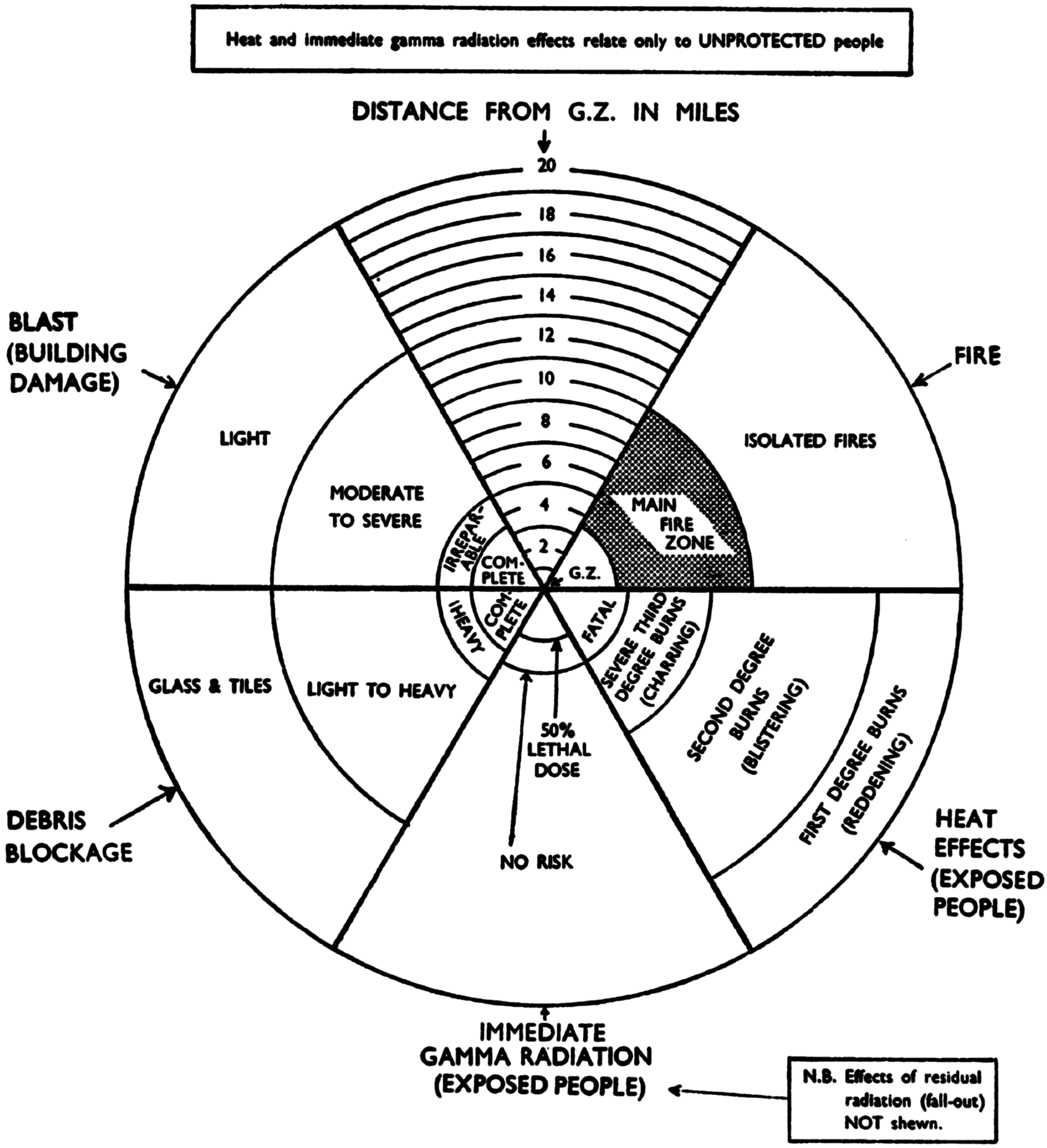


FIGURE 11

Combined effects (excluding residual radioactivity) from a 10 megaton ground burst bomb. Heat and immediate gamma radiation effects relate only to UNPROTECTED people.

A Fallout Forecasting Technique With Results Obtained at the Eniwetok Proving Ground

E. A. Schuert, USNRDL TR-139, United States Naval Radiological Defense Laboratory, San Francisco, Calif.

ADMINISTRATIVE INFORMATION

The work described herein is a part of the research sponsored by BuShips and the United States Army and locally designated as program 2, problem 3, phase 3. Its technical objective is AW-7 and it is described on RDB card NS 081-001.

SUMMARY

The problem: A fallout forecasting technique is needed to qualitatively describe the fallout hazard resulting from nuclear detonations. This technique should have such flexibility that its employment is valid for field use.

Findings: A summary of the latest experimental and theoretical considerations has resulted in the development of a technique whose complexity is dependent on the required accuracy of the results desired. This technique has been satisfactorily tested at the Eniwetok Proving Grounds for land surface and water surface bursts.

Particle size distribution in source model

All particle sizes were assumed at all elevations within the cloud except the lower two-thirds of the stem. However, to obtain agreement with past fallout measurements and with the optical diameter of the mushroom, it was necessary to fractionate the particle size distribution radially within the cloud. Otherwise, the computed fallout area about ground zero would be too large. The fractionation was specified as follows: particles of 1,000 microns in diameter and larger were restricted to the inner 10 percent of the mushroom radius or approximately the stem radius; those from 500 to 1,000 microns in diameter were limited to the inner 50 percent of the cloud radius. Since the relation of activity to particle size is some function of the particle diameter this fractionation tends to concentrate the activity about the axis of symmetry of the cloud.

Falling speeds **(feet/hour)**

J. M. Dallavalle, Mircomeritics, Pittman Publishing Corp., 1948.

Altitude	75 μ	100 μ	200 μ	350 μ	Altitude	75 μ	100 μ	200 μ	350 μ
0	3,060	5,040	11,700	21,600	65	4,190	7,480	26,100	51,100
5	3,120	5,240	12,300	22,900	70	4,110	7,320	27,600	55,200
10	3,200	5,480	12,900	24,100	75	4,010	7,150	28,100	59,700
15	3,270	5,750	13,700	25,500	80	3,910	6,960	27,800	61,900
20	3,360	5,980	14,400	27,100	85	3,800	6,770	27,100	67,800
25	3,470	6,160	15,300	28,800	90	3,720	6,640	26,500	71,300
30	3,570	6,380	16,300	30,800	95	3,620	6,470	25,800	77,300
35	3,720	6,640	17,500	33,000	100	3,550	6,340	25,300	80,200
40	3,870	6,910	18,600	35,300	105	3,470	6,180	24,800	75,800
45	4,040	7,200	19,800	37,800	110	3,400	6,050	24,000	74,200
50	4,210	7,520	21,400	40,600	115	3,330	5,930	23,700	72,600
55	4,420	7,860	23,200	44,600	120	3,260	5,800	23,400	71,100
60	4,200	7,700	24,400	47,200					

Experimental data from past tests at Eniwetok Atoll indicated that the particles were irregular in shape and had a mean density of 2.36 g/cu cm.

Time variation of the winds aloft

In most of the observations made at the Eniwetok Proving Ground, the winds aloft were not in a steady state. Significant changes in the winds aloft were observed in as short a period as 3 hours. This variability was probably due to the fact that proper firing conditions which required winds that would deposit the fallout north of the proving ground, occurred only during an unstable synoptic situation of rather short duration.

The forecasting technique described was employed by the fallout program at the Eniwetok Proving Ground to satisfy certain project requirements. One project had three ships equipped to collect fallout and their positions had to be determined for most efficient collection; another sampled the ocean for fallout; while another made an aerial survey of the contaminated area. The navigational schedules for these latter projects were based on the forecast fallout pattern. Operations were controlled through the program control center aboard the task force command ship where the forecasts were prepared.

The meteorological data was received from the weather ship at Bikini Atoll as well as from weather stations at Rongerik Atoll and Eniwetok Atoll. Furthermore all forecasts made by the task force weather central at Eniwetok Atoll were usually available aboard the command ship by facsimile through the ships weather station.

Upper air measurements were made at Bikini, Rongerik, and Eniwetok Atolls every 3 hours starting at H—24 hour and continuing until H+24 hour for any given detonation. The frequency of observations was usually increased during the period from H—6 to H—2 hours. The altitudes reached on the wind runs were remarkably high and gave perhaps the best set of winds-aloft measurements to date. The average termination altitude was approximately 90,000 feet with many runs over 100,000 feet. Such excellent coverage of the winds aloft was a major help in the fallout forecasting.

Fallout forecasts were made every 3 hours starting at H—24 hour using the *measured* winds available at the time. This process was continued up to shot time and from then on the technique of correcting for time variation was employed every 3 hours until the fallout event was completed. It was not feasible to correct for space variation and vertical motions during this period because of lack of time and data.

Fallout plots

The fallout forecasts determined at the weapons-test operation were based entirely on measured data and quantitatively considered time variation of the wind. No space variation corrections or computed values of vertical motions were employed in their construction.

A and B were land-surface detonations, C and D were water-surface shots.

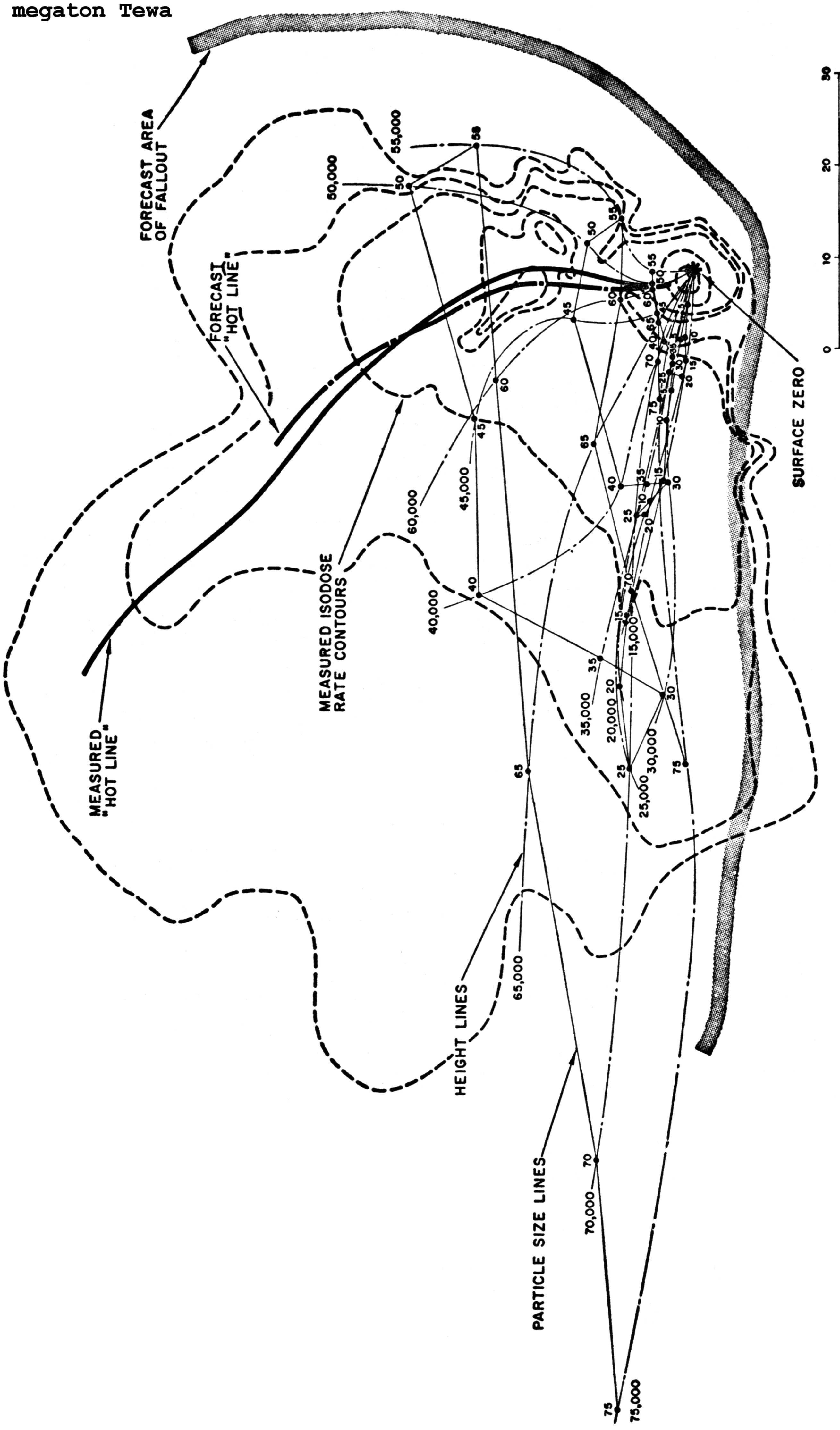
The comparison is excellent for all shots except B.

SUMMARY

The fallout forecasting technique described in this report was successfully employed for both land surface and water surface detonations at the Eniwetok Proving Ground. With known meterological data such a technique will successfully qualify the area of fallout and indicate qualitatively the relative intensity of radiation.

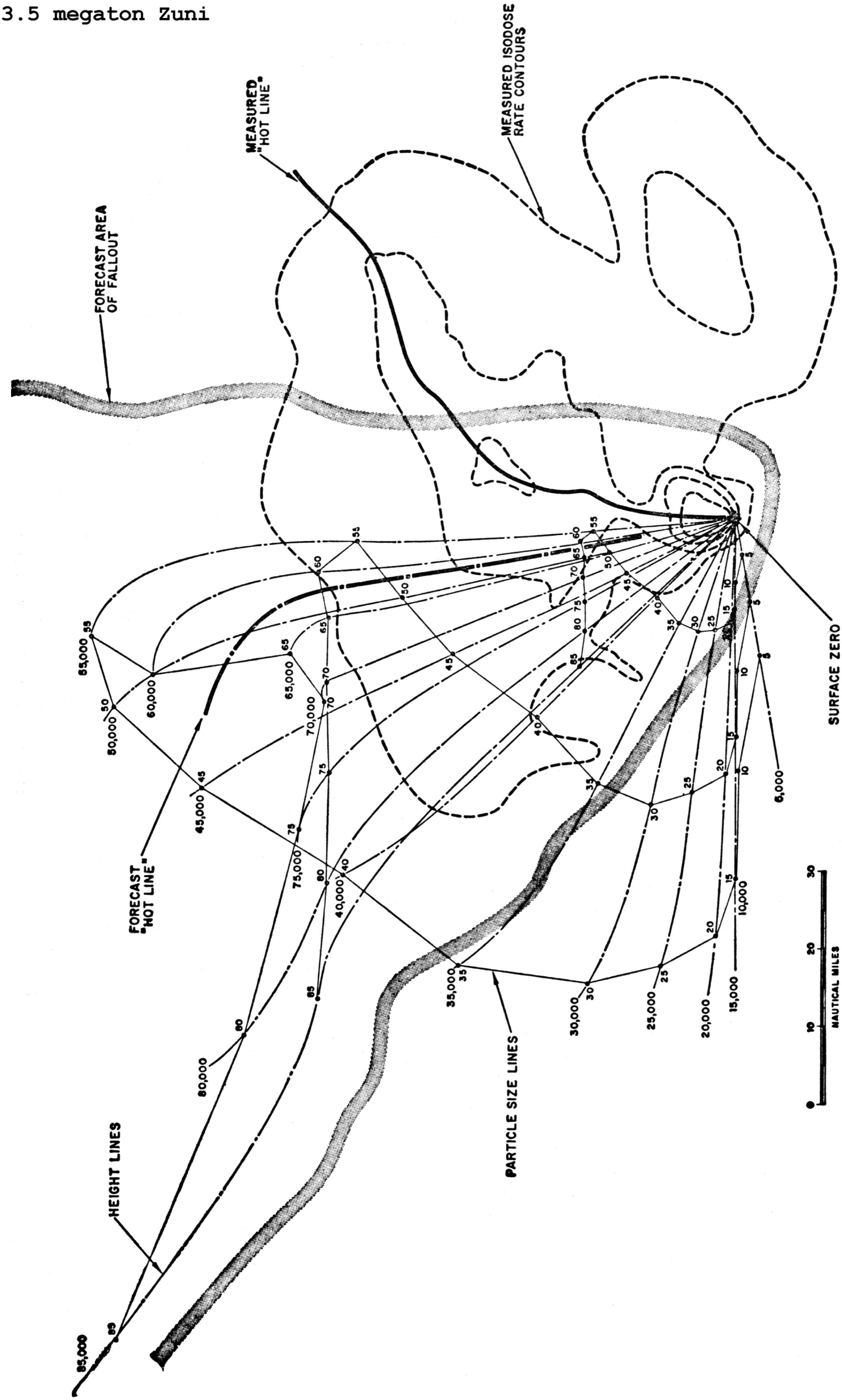
"Height lines" are deposit locations for all particles falling from a fixed altitude within the mushroom cloud. "Size lines" are deposit locations of a fixed particle size from various altitudes. A height line from the base of the mushroom disc is the "hot line".

5 megaton Tewa



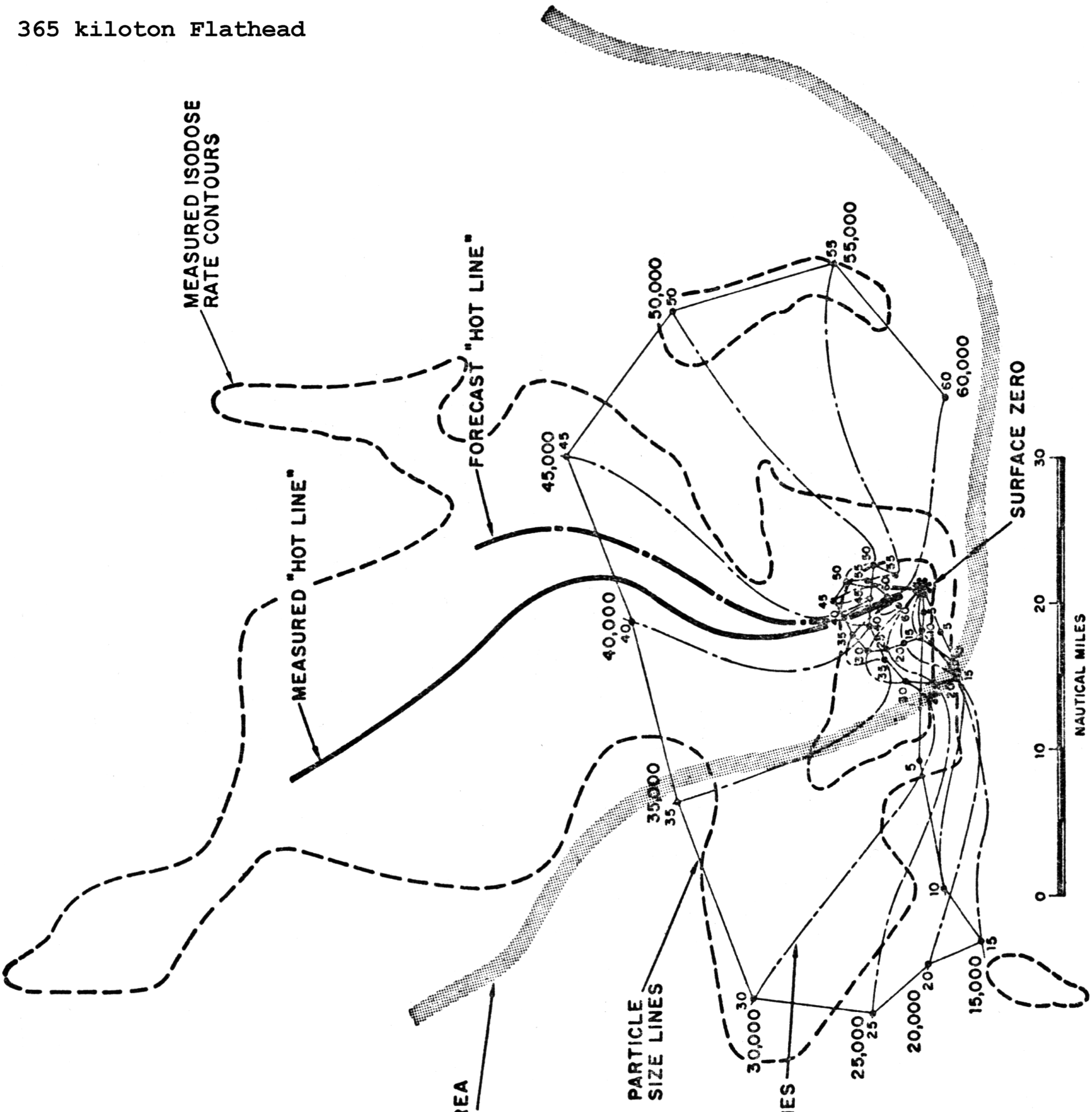
Comparison of fallout forecast with test results—shot A

3.5 megaton Zuni



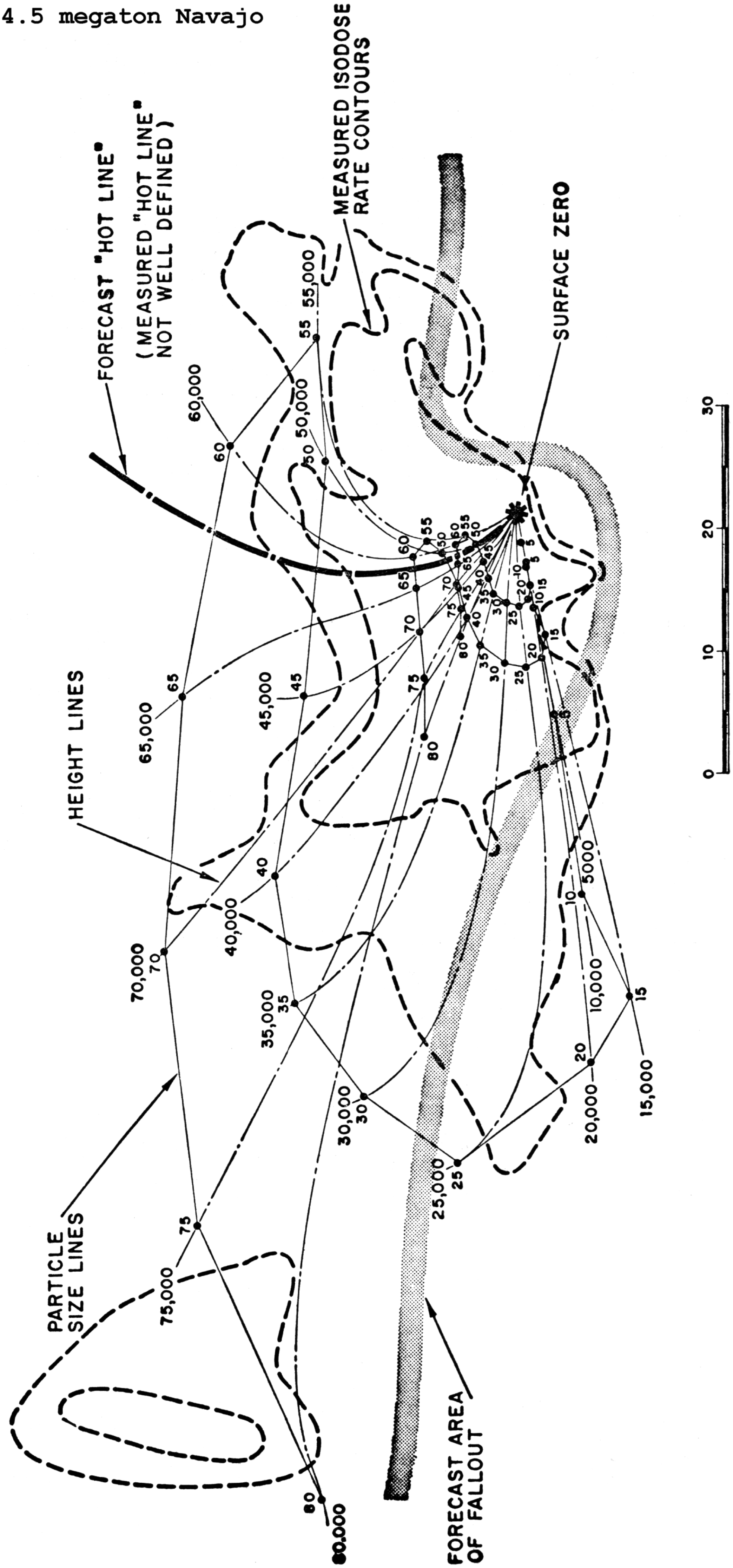
Comparison of fallout forecast with test results—shot B.

365 kiloton Flathead



Comparison of fallout forecast with test results—shot C.

4.5 megaton Navajo



Comparison of fallout forecast with test results—shot D.

SECRET

WT-615

This document consists of 84 pages

No. 254 of 265 copies, Series A

Report to the Scientific Director

NATURE, INTENSITY, AND DISTRIBUTION OF FALL-OUT FROM MIKE SHOT

(The first 10 megaton H-bomb test, 1952)

By

W. B. Heidt, Jr., LCDR, USN
E. A. Schuert
W. W. Perkins
R. L. Stetson

U. S. Naval Radiological Defense Laboratory
San Francisco, California
April 1953

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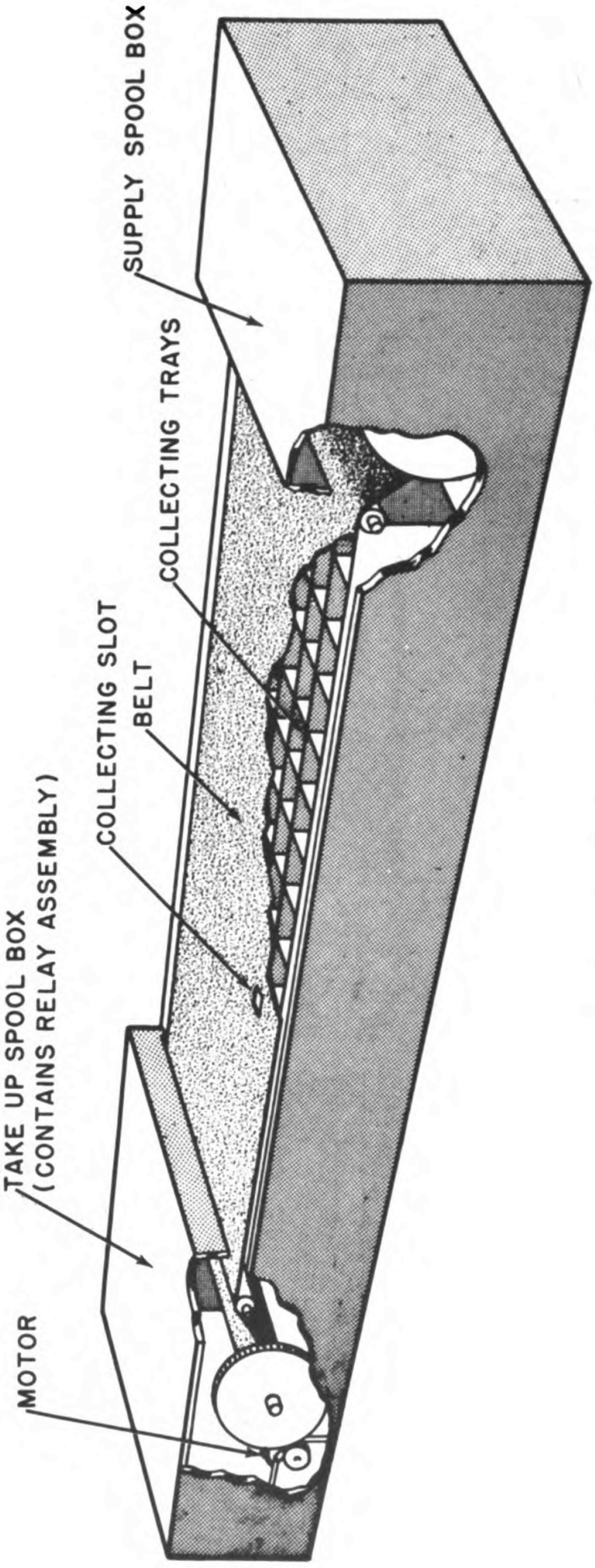

Fig. 3.2—Differential fall-out collector.

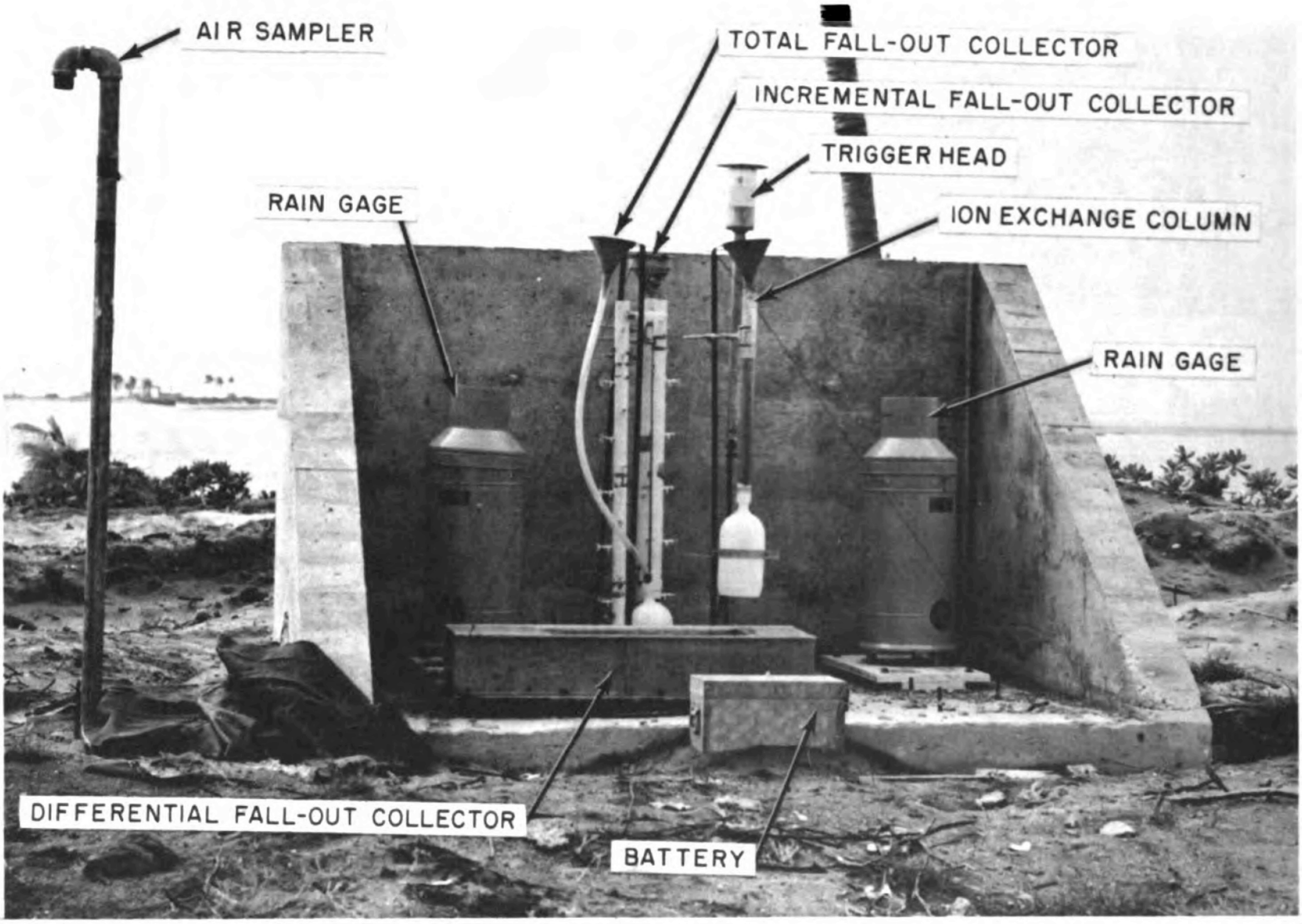

Fig. 3.8—A typical land station.

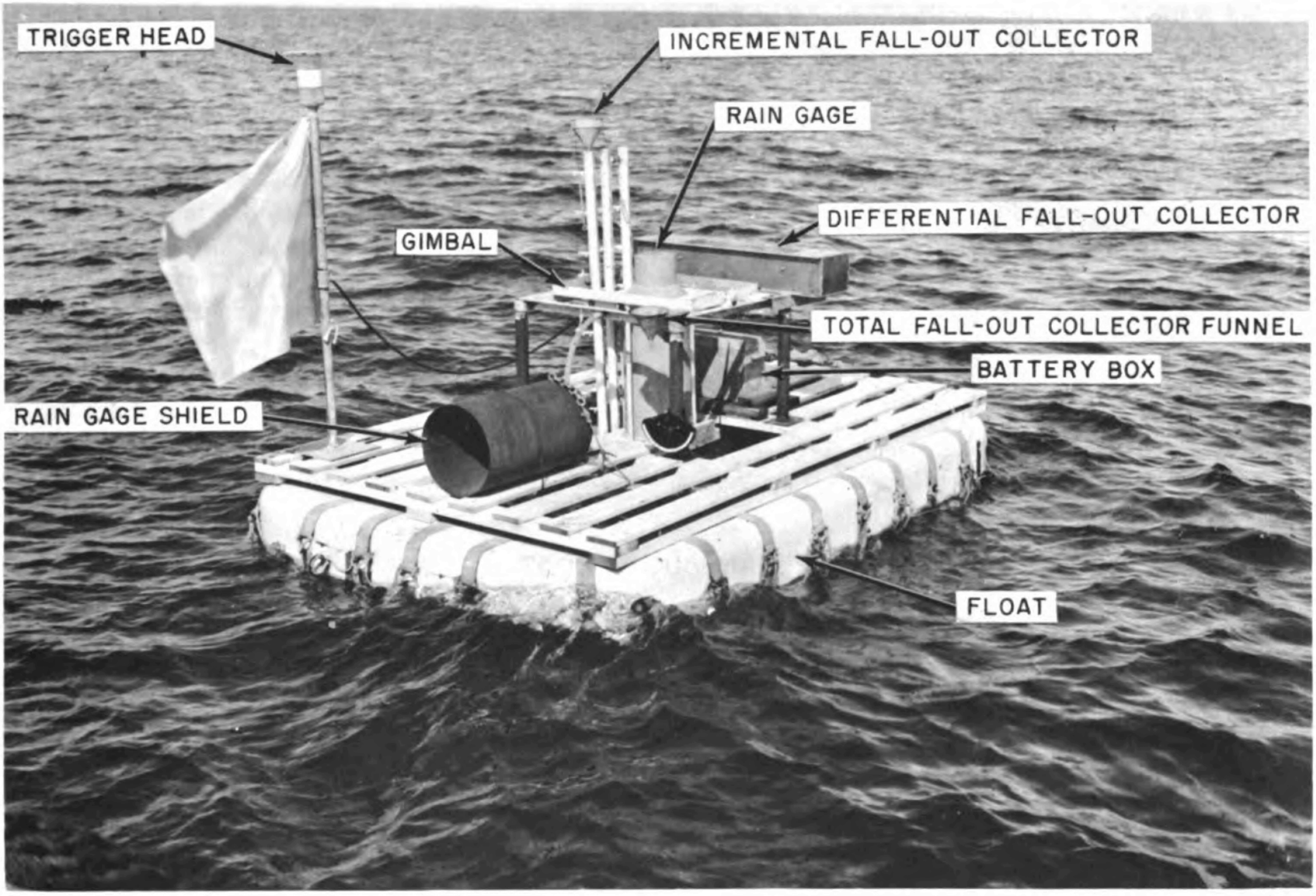

Fig. 3.9—A typical lagoon station.

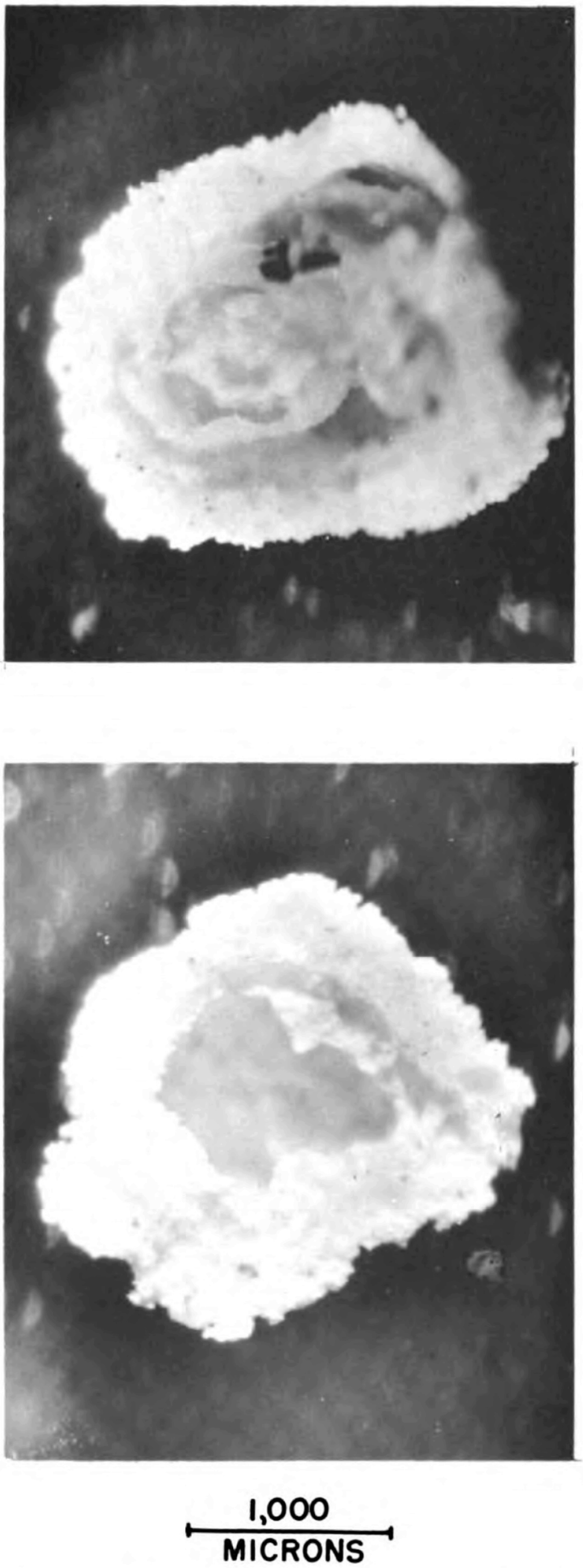

Fig. 4.4—Inverted view of typical particles removed from life-float decking.

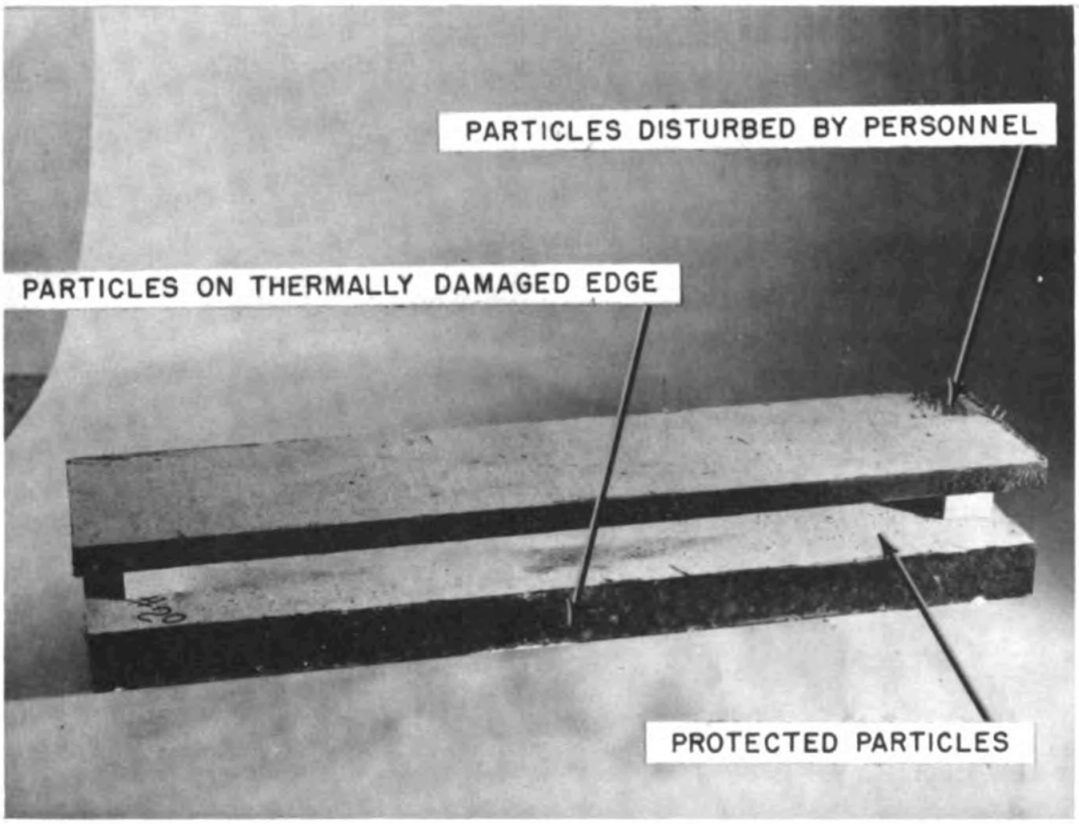

Fig. 4.5—Typical life-float section.

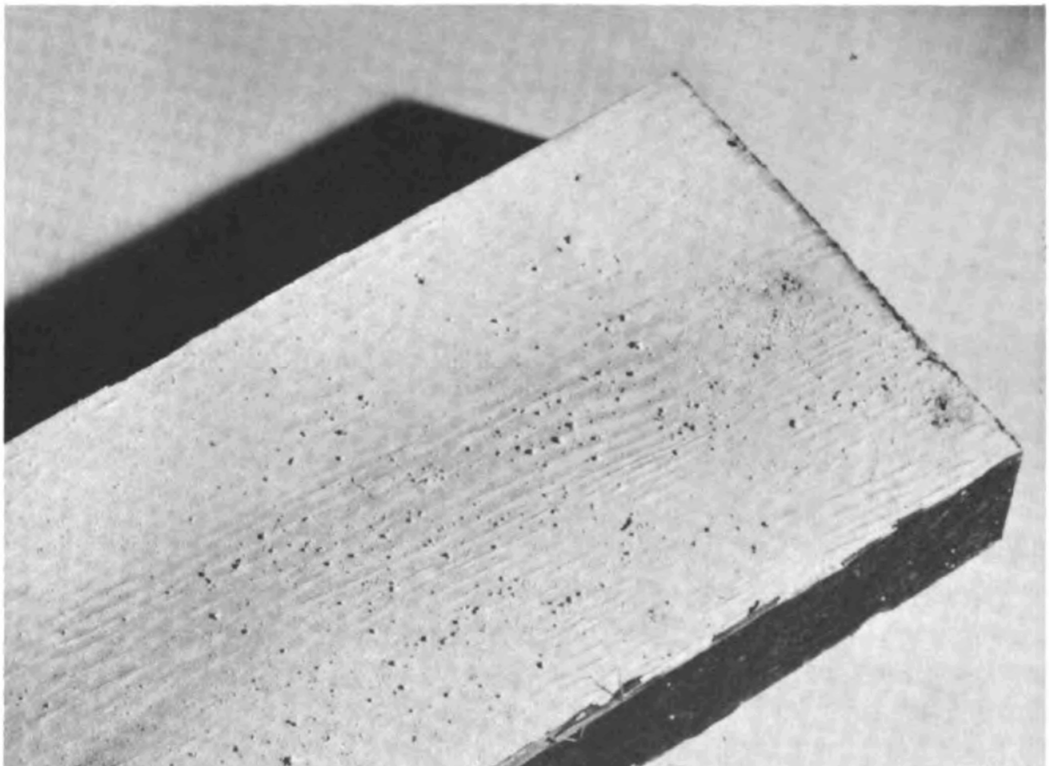

Fig. 4.6—Particle deposition on life-float decking (lower deck of Fig. 4.5).

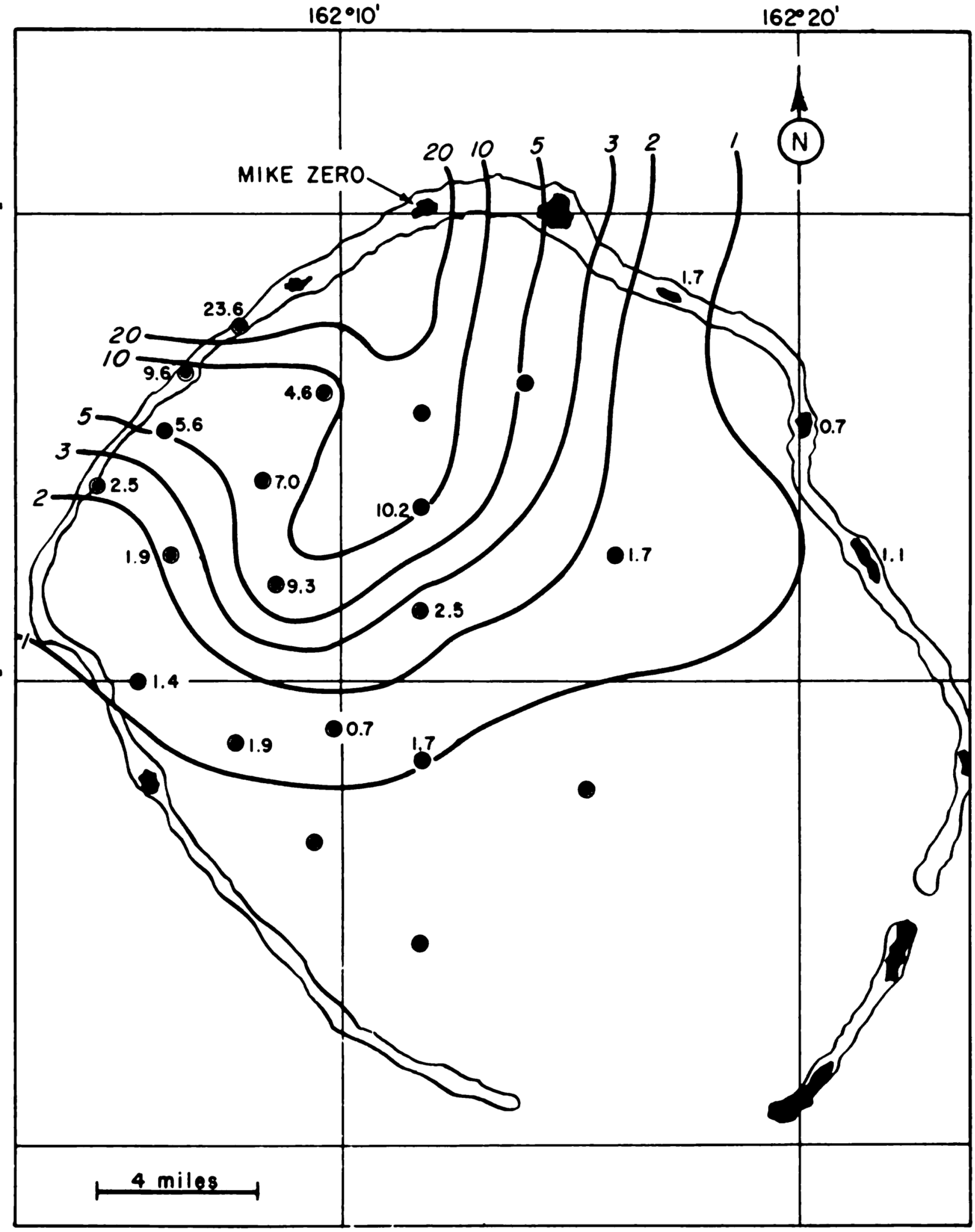

Fig. 4.8—Mass distribution of fall-out (g/sq ft).

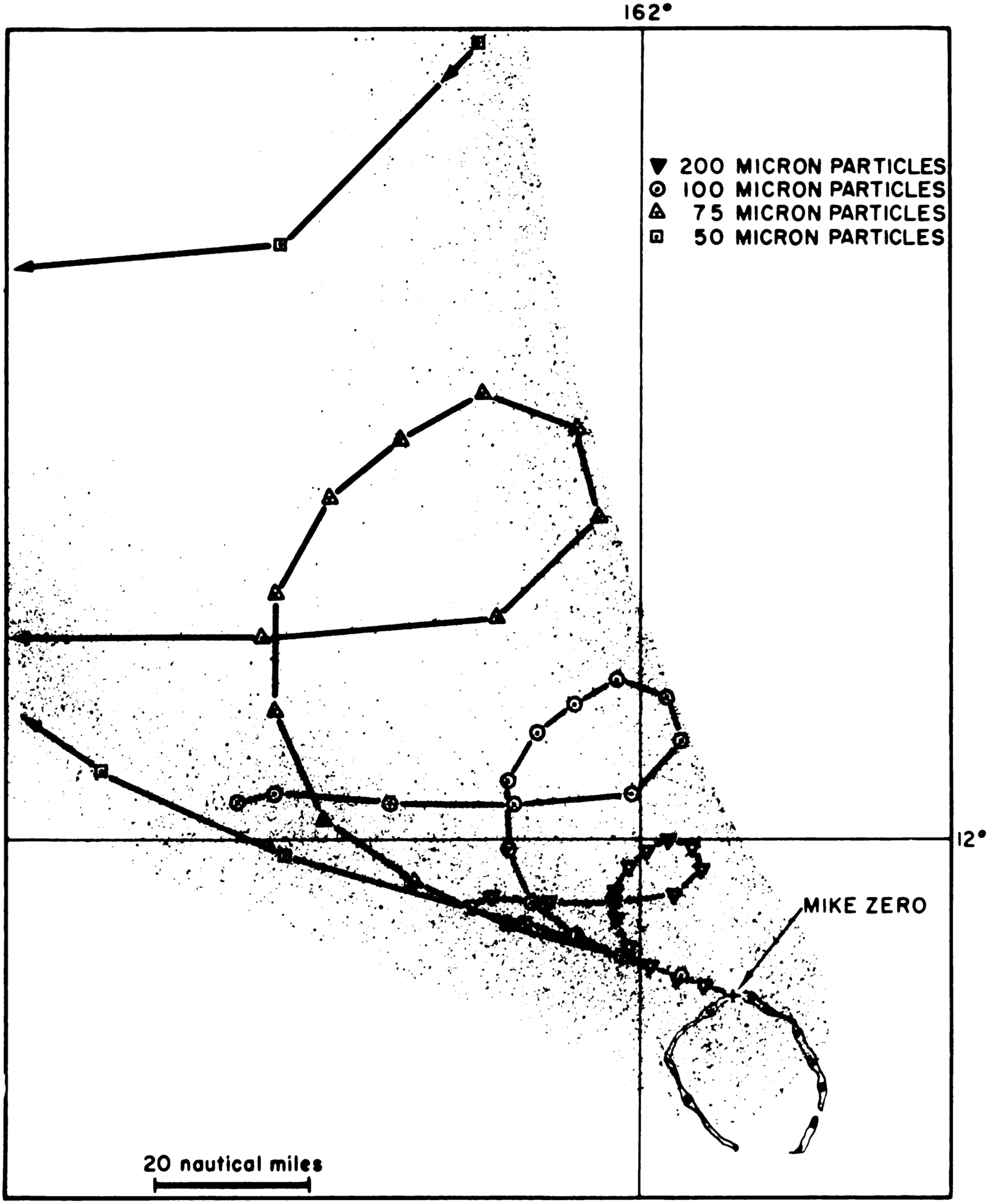

Fig. 6.1—Predicted area of primary fall-out.

HEAVY ISOTOPE ABUNDANCES IN MIKE THERMONUCLEAR DEVICE. Diamond, H. (Argonne National Lab., Ill.); Fields, P. R.; Ghioroso, A.; Thompson, S. G.; Browne, C. I.; Smith, H. L.; et al. Phys. Rev., 119: 2000-4(Sept. 15, 1960).

The Nov. 1, 1952, thermonuclear explosion ("Mike") produced all of the uranium isotopes ^{239}U, ^{240}U, ... ^{255}U through multiple neutron capture by ^{238}U. The long-lived products of successive β decays from these isotopes were measured mass spectrometrically and radiometrically. The logarithms of the abundances decline smoothly with increasing mass number; the even-mass abundances slightly exceed the geometric mean of adjacent odd-mass abundances. Some nuclear properties of neutron-rich heavy nuclides, not subject to ordinary investigation, are inferred.

NUCLEAR DECAY PROPERTIES OF HEAVY NUCLIDES PRODUCED IN THERMONUCLEAR EXPLOSIONS: PAR AND BARBEL EVENTS. Phys. Rev., 148: 1192-8(Aug. 19, 1966). (UCRL-14500).

The nuclear decay properties of heavy nuclides ($A \leq 257$) produced in two low-yield thermonuclear explosions, the Par and Barbel events, were studied with the following results. The α-decay branching of ^{253}Cf was observed, $E_\alpha = 5.978 \pm 0.005$ MeV, $\alpha/(\alpha + \beta^-) = 0.31 \pm 0.04\%$. The α-decay branching of ^{255}Es was observed, $E_\alpha = 6.300 \pm 0.003$ MeV, $\alpha/(\alpha + \beta^-) = 8.5 \pm 0.3\%$. The spontaneous fission half life of ^{250}Cm was remeasured and was found to be $1.74 \pm 0.24 \times 10^4$ years. Upper limits for the half lives of ^{252}Cm and ^{251}Bk were set at 2 and 3 days, respectively. The existence of 80-day ^{257}Fm was confirmed; a sample of ^{257}Fm from the Par event decayed with a half life of 94 ± 10 days.

(LA-DC-8103) PRODUCTION OF HEAVY ELEMENTS IN A RECENT LOS ALAMOS THERMONUCLEAR TEST. Hoffman, Darleane C. (Los Alamos Scientific Lab., Univ. of California, N. Mex.). [1966]. Contract W-7405-eng-36. 8p. (CONF-660817-3). Dep. mn.

A low-yield thermonuclear device, designed to give a high-neutron-flux region for the purpose of producing heavy elements by multiple-neutron capture, was recently tested underground in Nevada. This device, Cyclamen, containing ^{238}U and ^{243}Am target material, was the most successful heavy element producer to date, giving an order of magnitude more ^{257}Fm than any previous Nevada test.

FISSION AND THE SYNTHESIS OF HEAVY NUCLEI BY RAPID NEUTRON CAPTURE. Bell, George I. (Los Alamos Scientific Lab., N. Mex.). Contract W-7405-eng-36. Phys. Rev., 158: 1127-41(June 20, 1967). (LA-DC-8513).

The role of fission is examined in the synthesis of heavy nuclei by multiple capture of neutrons in thermonuclear explosions. Evidence from the recent Tweed and Cyclamen experiments indicating that neutron-induced fission is a serious source of depletion in neutron capture chains which start from targets of ^{242}Pu and ^{243}Am is reviewed.

SECRET

WT-617

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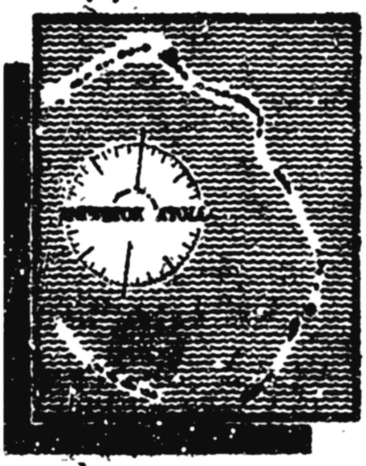
Operation IVY

PACIFIC PROVING GROUNDS

November 1952

Project 5.4b

FALL-OUT AND CLOUD-PARTICLE STUDIES



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JOINT TASK FORCE 132

CHAPTER 2

BACKGROUND

2.1 INTRODUCTION

In past atomic detonations the results obtained from projects concerned with fall-out have not always been consistent. Fall-out results have been influenced by methods of collection and analysis, weather conditions, type and height of shot, and yields of the devices. However, results from past operations do show some trends which are of interest in this study.

2.2 SIGNIFICANCE OF RADIOACTIVITY AND PARTICLE SIZE

Radioactive fall-out can be both an external and an internal hazard to personnel.

External radiation can cause injury to body tissues of living organisms in the area of fall-out if the tissues are exposed to a large amount of radiation in a short time. One hundred roentgens (in a matter of minutes) has been suggested by the USAF Air Surgeon as a lifetime radiation dose which a soldier might be given in time of war.[1] This dose might produce some temporary blood-cell changes and a case of radiation sickness, but no permanent injury would be incurred by the soldier. No evacuation would be contemplated, and there should be no reduction in combat effectiveness.[2]

The internal hazard due to an aerosol depends, to a great extent, on the size of the radioactive particles inhaled. The nose will filter out almost all particles over 10 μ in diameter and about 95 per cent of all particles exceeding 5 μ. Particles of 0.5 to 5 μ are most likely to be retained in the lungs, or they may be transferred to the blood stream and the lymphatic system.[3,4] Internal contamination will also depend on the length of exposure to radioactive particles and the respirator rate. Particles of any size may be taken into the mouth, thus constituting an internal hazard.

In Operation Jangle Project 2.7, lung sections of dogs and sheep were examined.[4] Many crystalline particles 2 μ and under were found. The few radioactive particles found were in clusters and were alpha, alpha and beta, or beta emitters. Most particles either were never radioactive or had decayed to the point where no radioactivity could be detected at the time of examination. It is possible that the radioactive material had dissolved off the inert particles and had been redistributed. Lung tissues contained significant amounts of radioactivity as determined by counting techniques. The total internal dose was less than 1 per cent of the external dose from both shots, and the animals did not acquire significant amounts of radioactivity by inhalation or ingestion.

Radioactive fall-out may contaminate equipment to the point where it cannot be used safely for a period of time. Particles in the micron and submicron ranges are more difficult to remove mechanically than are larger particles. If these particles are radioactive, they can

present a serious contamination problem. Very large particles are more easily detected, measured, and removed by brushing and hosing.

2.3 PARTICLE SIZE, ACTIVITY, AND DISTANCE

Fall-out dust picked up on the USS Independence after Operation Crossroads Able shot indicated that the specific activity became larger as the particle radius decreased from 550 to 10 μ.[5] About 20 per cent of the total activity in the dust of the ventilation system of the USS Crittenden after Baker shot was in the 44- to 210-μ range; 51 per cent of the total activity in the same dust sample was 10 μ or less.[6] Both ships were approximately 600 yards from their respective ground zeros.

A moderate amount of activity[7] (up to 24 per cent) was found in particles 20 μ or smaller from Greenhouse Dog shot fall-out by Project 6.4. Greenhouse Easy shot samples indicated that greater than 92 per cent of the activity in the samples was associated with particles 20 μ or larger.

Estimates by the Greenhouse Radiological Safety Unit (Rad-Safe)[8] of the size of Dog shot radioactive-fall-out particles were made by comparison with red blood cells 7 to 8 μ in size. Thus examined, particles appeared to be 50 to 150 μ in diameter. Studies of mechanically separated particles indicated that fall-out during the first 6 hr after Dog shot was no smaller than 20 to 25 μ.

On Operation Jangle, Project 2.5a-1 sampled gross aerosol 7 ft above the ground with cascade impactors.[9] In an examination of the slides for particle-size distribution, no particles were found to be larger than 40 μ; the impactors may have shattered the larger particles. The tendency to smaller particle sizes in the aerosol at increasing distances from ground zero was observed after both shots. The underground-shot gross aerosol initially possessed a distribution containing slightly larger particles [number median diameter (NMD) 1.5 μ] than the surface shot (NMD, 1 μ). The underground-shot particles fell out faster than the surface-shot particles, and 50,000 ft from ground zero gross aerosol from both shots had an NMD distribution of less than 0.1 μ. No over-all correlation of activity with particle size could be made with the cascade impactors or any other sampling instrument used on this project. However, correlations were made with the data from some individual stations, showing the percentage of active particles from the surface-shot fall-out to be 0.01 per cent for 1-μ particles, whereas the percentage of active particles for underground fall-out particles of 100 μ was found to be 20 per cent.

Some Jangle underground-shot gross-fall-out samples were radioautographed.[10] Seventeen to eighteen per cent of all counted particles above 149 μ were radioactive, whereas only 0.9 to 4.2 per cent of the smaller size fractions were radioactive. These particles were collected 2000 ft northeast of ground zero.

Project 2.5a-2 found the gross-particle NMD for the underground shot to be 0.2 μ by electron-microscope analysis.[11] The radioactive-particle NMD was 1.4 μ. However, more than 93 per cent of the activity from both shots was associated with particles 20 μ or larger. Over-all area relations of activity with distance were not pronounced on the surface-shot fall-out. However, the underground-shot activity varied directly with distance from ground zero (within the limits of the experiment). For both shots the specific activity increased with distance.

The bulk of all radioactive dust collected at distances greater than 200 miles from ground zero was found to be less than 5 μ in diameter.[12]

2.4 RATE OF FALL-OUT

During the Sandstone tests[7] a secondary fall-out was reported from Kwajalein on Yoke + 1 day, 36 hr after the explosion and 400 miles southeast of Eniwetok. The fall-out occurred as radioactive rain that fell intermittently during a 10-hr period. The maximum activity was about 6 to 10 mr/hr.

On Operation Greenhouse[7] fall-out occurred over the southern half of the Atoll, starting about 3 hr after Dog shot and reaching a peak about 6 hr later. Activities ranged from 30 mr/hr at Eniwetok to 250 mr/hr at Rigili, from 1100 to 1700 hr on D-day. Fall-out from Easy shot was concentrated in the northern third of the Atoll. Activities ranged from 120 mr/hr at Piiraai to 3 r/hr at Bogallua on E-day, from 0700 to 1400 hr. A small secondary fall-out occurred on Parry and Eniwetok on E + 1.

Fall-out from the Jangle surface shot[11] was collected for 2 hr along a long narrow swath N10°E from ground zero. The first fall-out reached a station 14,000 ft from ground zero in 8 min. A second wave reached this section 60 to 100 min later. The first wave also reached a 20,000-ft station in 10 min; therefore the initial fall-out traveled approximately 20 to 23 mph to the two stations from ground zero. However, the surface wind actually traveled 2 mph; so the fall-out must have been carried by higher speed upper-altitude winds. Heavy fall-out from the Jangle underground shot covered a wider area, generally north-northeast from ground zero. There were three waves of fall-out recorded at stations 2000 and 3000 ft north of ground zero during the first 10 min after the detonation. At 14,000 and 20,000 ft north of ground zero, there was one pronounced wave during the first 15 min after shot time. Surface-wind velocity was only about 4.5 mph, whereas it was 21 mph at the top of the underground-shot cloud. There was a series of secondary fall-outs 30 to 100 min after the shot at the more distant stations. Individual sample activities from both shots were of the order of 10^8 counts/min during these peaks.

2.5 PHYSICAL CHARACTERISTICS OF RADIOACTIVE PARTICLES

Most of the Greenhouse radioactive particles were in the form of black spheres, which occurred as individual particles, particles adhering to coral grains, and clusters of spheres with transparent granules. The size of most of the particles ranged from 2 to 500 μ.

The Jangle radioactive particles were observed to be, generally, glassy spheres and grains.[11] Their elemental composition was the same as the inert soil, except that boron and carbon were missing. The Jangle fall-out was of a heterogeneous nature.

2.6 DECAY SLOPES

Decay slopes of a limited number of Operation Jangle underground-fall-out fractions, collected at distances from 2000 to 6000 ft northwest, north, or northeast from ground zero, varied from −0.45 to −1.44, with most of the slopes in the range of −1.1 to −1.3 between H + 1000 to H + 2000 hr.[9] It appears that the absolute values of the decay slopes increase as particle diameter decreases. Also, within the limitations of the data, the absolute value of the decay slopes appears to be relatively highest on the northeast leg from ground zero. The slopes decrease on the north leg and decrease further on the northwest leg. However, another investigator[13] found that decay slopes did not vary much for particles larger than about 300 μ. It is not known where these samples were collected in the test area.

2.7 RADIOCHEMISTRY

Previous radiochemical studies on samples collected from nuclear detonations have indicated a variation in fission-product activities with particle size.[7,9,14]

2.8 SUMMARY

An extensive review of the fall-out data given in the previous sections, including information on collecting apparatus, particle-size distribution of fall-out and aerosol near the surface,

Table 4.1—SITE CODES FOR ENIWETOK ATOLL

Code letter	Code name	Island
A	Alice	Bogallua
B	Belle	Bogombogo
C	Clara	Ruchi
D	Daisy	Cochiti
E	Edna	San Ildefonso
F	Flora	Elugelab
G	Gene	Teiteiripucchi
H	Helen	Bogairikk
I	Irene	Bogon
J	Janet	Engebi
K	Kate	Muzin
L	Lucy	Kirinian
M	Mary	Bokonaarappu
N	Nancy	Yeiri
O	Olive	Aitsu
P	Pearl	Rujoru
R	Ruby	Eberiru
S	Sally	Aomon
T	Tilda	Biijiri
U	Ursula	Rojoa
V	Vera	Aaraanbiru
W	Wilma	Piiraai
Y	Yvonne	Runit
Z	Zona	"M" Site
AA	Alvin	Chinieero
BB	Bruce	Aniyaanii
CC	Clyde	Chinimi
DD	David	Japtan
EE	Elmer	Parry
FF	Fred	Eniwetok
GG	Glenn	Igurin
HH	Henry	Mui
II	Irwin	Pokon
JJ	James	Ribaion
KK	Keith	Giriinien
LL	Leroy	Rigili
MM	Mack	Lagoon photo tower (formerly called "Coral Head")

Table 4.2—DISTANCES FROM STATIONS TO MIKE AND KING SHOT GROUND ZEROS

Station	Distance to ground zero,* ft	
	Mike shot	King shot
A	17,423	78,100
B	13,462	76,500
C	7,799	73,500
I	9,270	64,600
J_n	18,895	53,800
J_s	18,905	53,800
K	21,521	49,800
L	23,756	47,300
M	31,053	40,700
N	34,852	37,800
O	36,943	35,100
P	40,274	32,500
R_n	44,532	29,800
R_s	44,587	29,800
S	47,899	26,600
U	53,300	22,300
V	54,820	19,700
W	57,211	15,100
Y_n	75,489	4,270
Y_s	75,495	4,270
BB	102,687	35,100
DD_n	110,949	47,600
DD_s	110,957	47,600
EE_n	115,565	55,800
EE_s	115,573	55,800
FF_n	124,609	70,000
FF_s	124,618	70,000
GG	117,510	87,600
KK_n	107,340	93,500
KK_s	107,350	93,500
LL_n	83,815	98,100
LL_s	83,817	98,100
MM	47,712	37,400

*King shot distances were estimated from Navy Hydrographic Office map 6033; Mike shot distances were determined by survey.

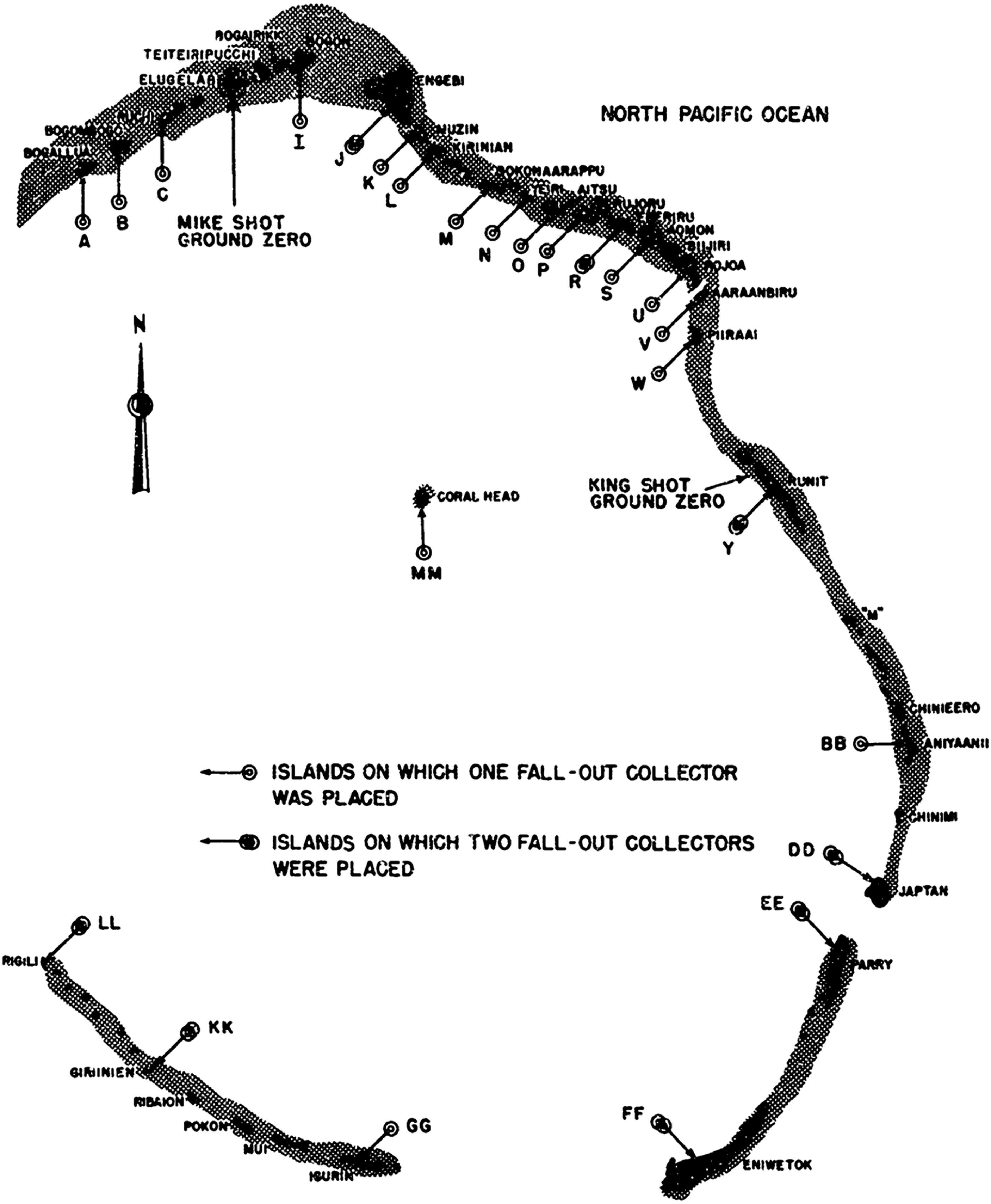

Fig. 4.1—Fall-out station locations at Eniwetok Atoll.

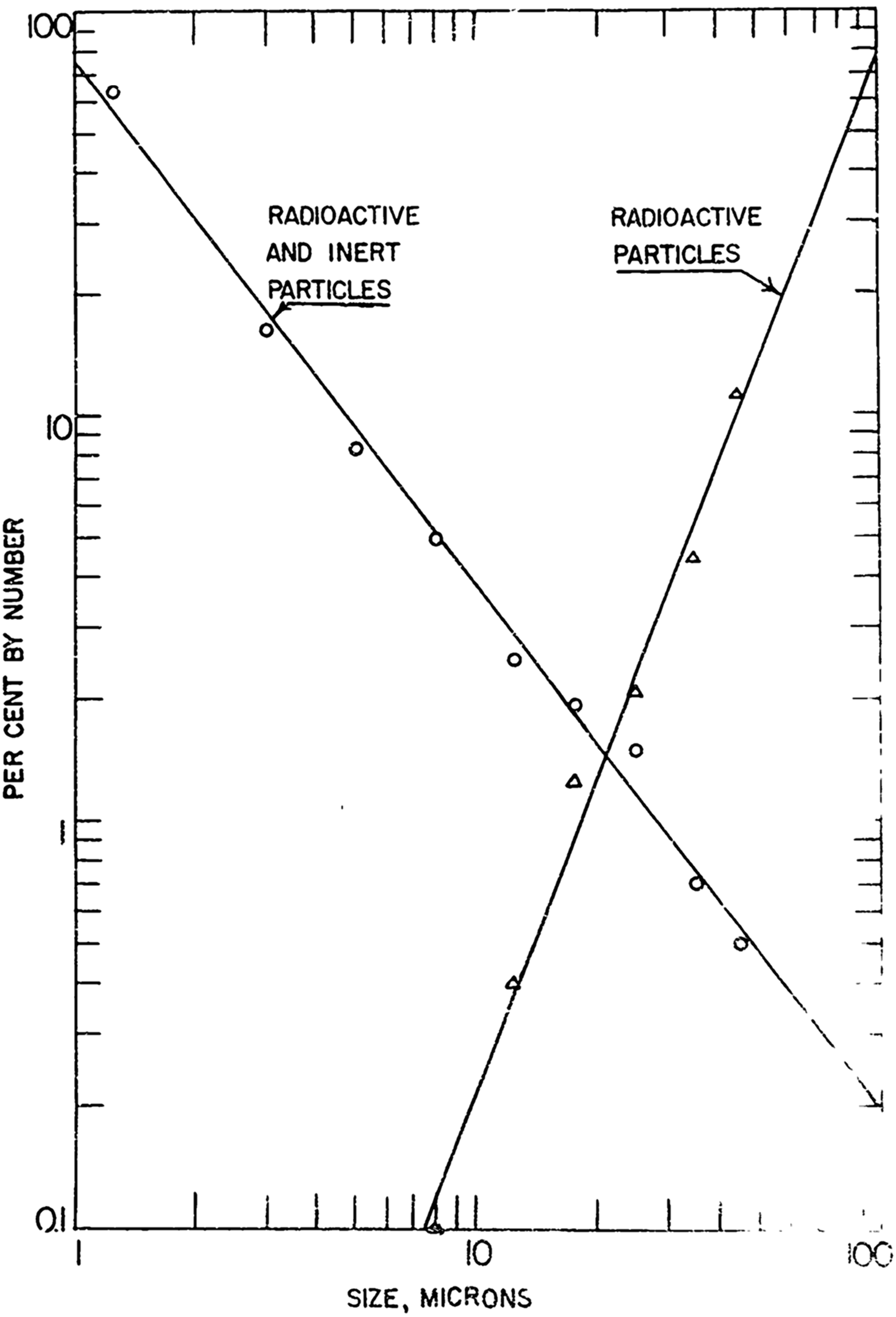

Fig. 6.2—Average percentage of total particles counted in each size range and average percentage of radioactive particles in each size range, Mike shot.

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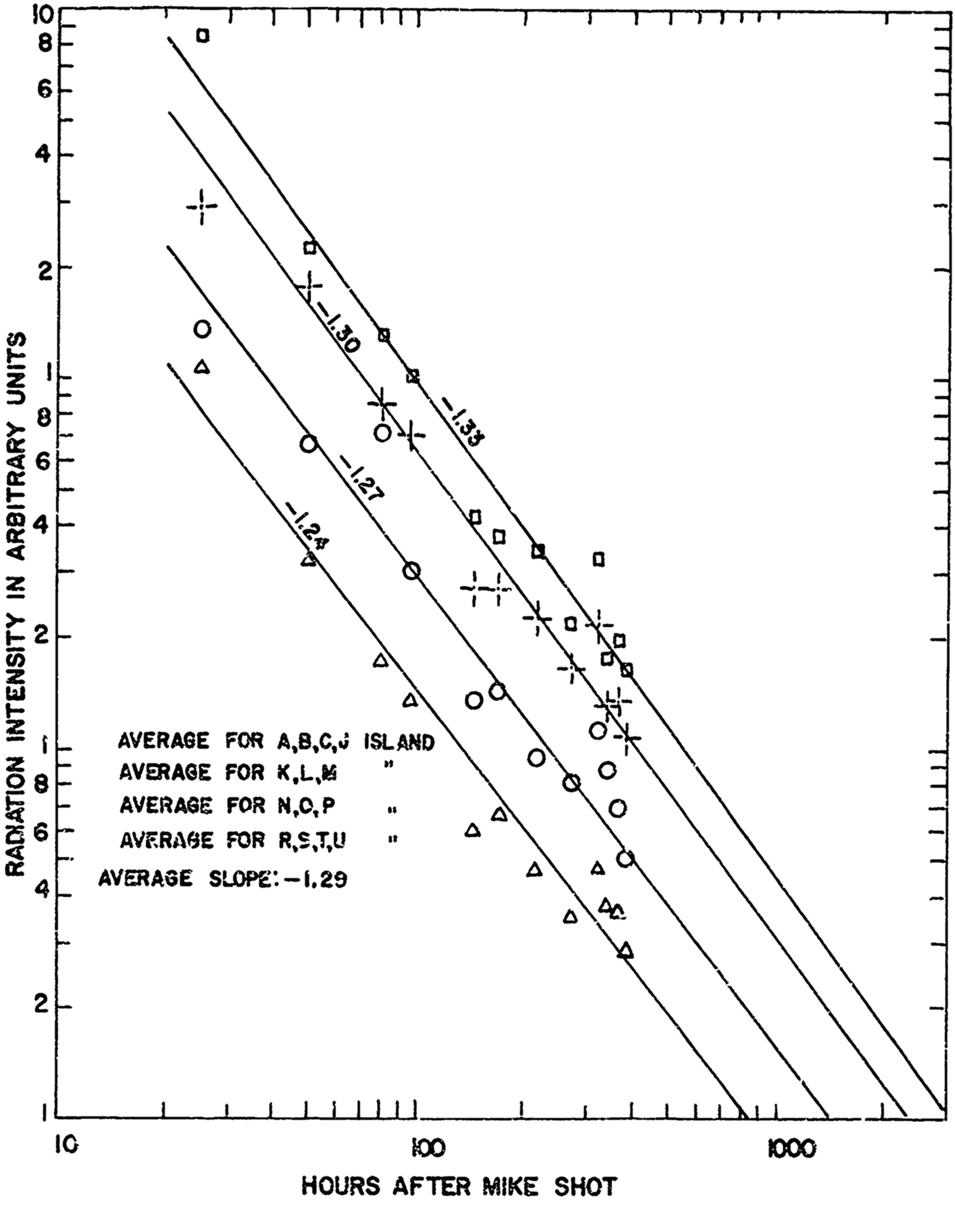

Fig. 4.3—Decay of residual gamma activity after Mike shot.

CHAPTER 6

CONCLUSIONS

6.1 RESIDUAL GAMMA ACTIVITY

1. Land areas were contaminated to a dangerous degree more than 12 miles upwind from Mike shot. An LD_{100} dose of residual gamma radiation would have been received by a person remaining 10 miles upwind from ground zero for the 24-hr period following Mike shot. Four days after Mike shot, a person would have received an LD_{50}/30 days' dose in 24 hr as far as two miles upwind from ground zero.

2. The level of contamination from King shot was much lower than from Mike shot. The highest gamma intensity found during any aerial survey was about 10r/hr 40 min after the shot.

6.2 AERIAL-SURVEY PROCEDURE

1. The aerial-survey system used is adequate with modifications for accurate navigation. The AN/PDR-39 proved satisfactory as a survey instrument for measuring the dose rate within a limited range of gamma energies. However, there is no assurance that the instrument is sensitive to low-energy scattered radiation.

2. H-13 helicopters are preferable to the H-19 type for making aerial surveys. An accurate altimeter below 300 ft is desirable.

3. The AN/PDR-39 should be replaced by a survey meter with a faster response time and with a single logarithmic scale.

4. The survey meter used should incorporate a probe that could be suspended below the helicopter.

5. A recording device with a response time faster than that of the Esterline-Angus recorder should be used to record the survey data.

6. It is important that aerial surveys be made only by personnel thoroughly trained in the procedures to be used.

WT-915

This document consists of 172 pages

No. 238 of 240 copies, Series A

OPERATION CASTLE

Project 2.5a

DISTRIBUTION AND INTENSITY OF FALLOUT

REPORT TO THE SCIENTIFIC DIRECTOR

by

R. L. Steton
E. A. Schuert
W. W. Perkins
T. H. Shirasawa
H. K. Chan

This document regraded
From SECRET
To UNCLASSIFIED
Date 14 July 82
Authority DNA LTR 6/14/82

(The Castle-Bravo 15 megaton H-bomb test of 1 March 1954, which contaminated a Japanese tuna trawler and islanders)

January 1956

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U. S. Naval Radiological Defense Laboratory
San Francisco 24, California

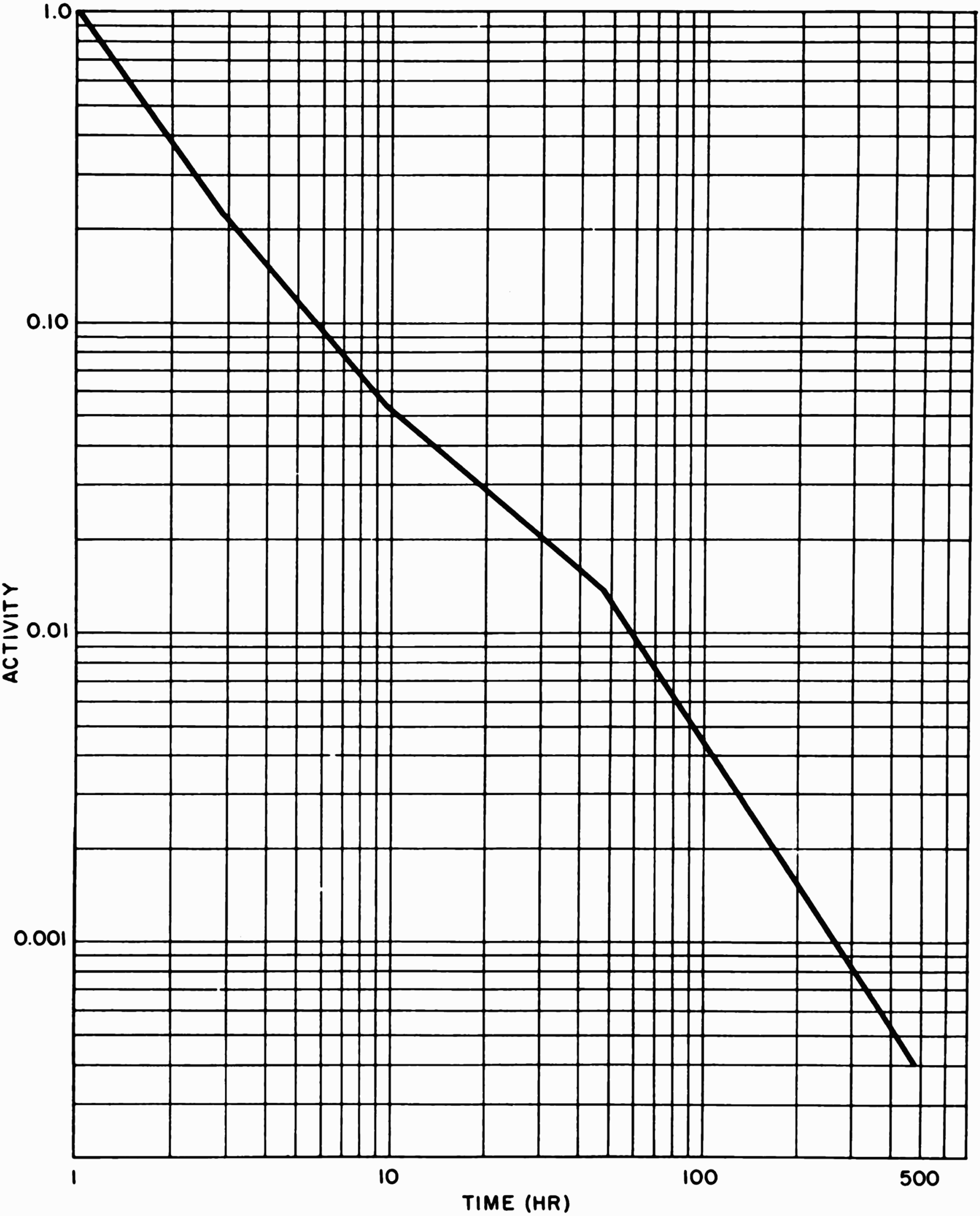

Fig. 5.3 Composite Gamma Ionization Decay Curve

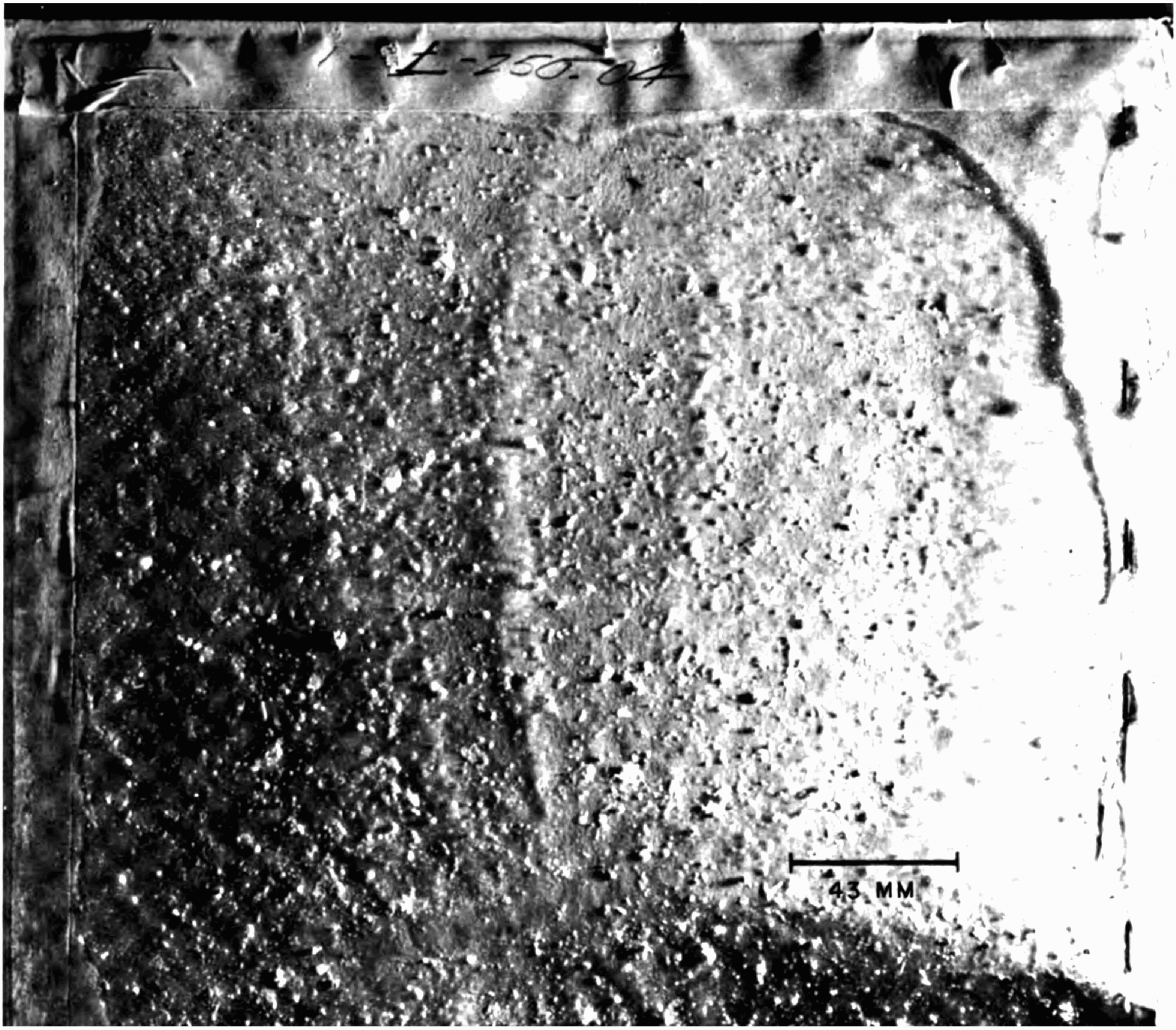

Fig. 5.10 Shot 1, Fallout Particulate, Station 250.04

This is a raft downwind in Bikini Lagoon, which received a land equivalent of 113 R/hr (1 hour reference gamma dose rate), according to Figures 2.2 and 6.1. Land equivalent dose rates were 7 times the raft dose rate in the lagoon.

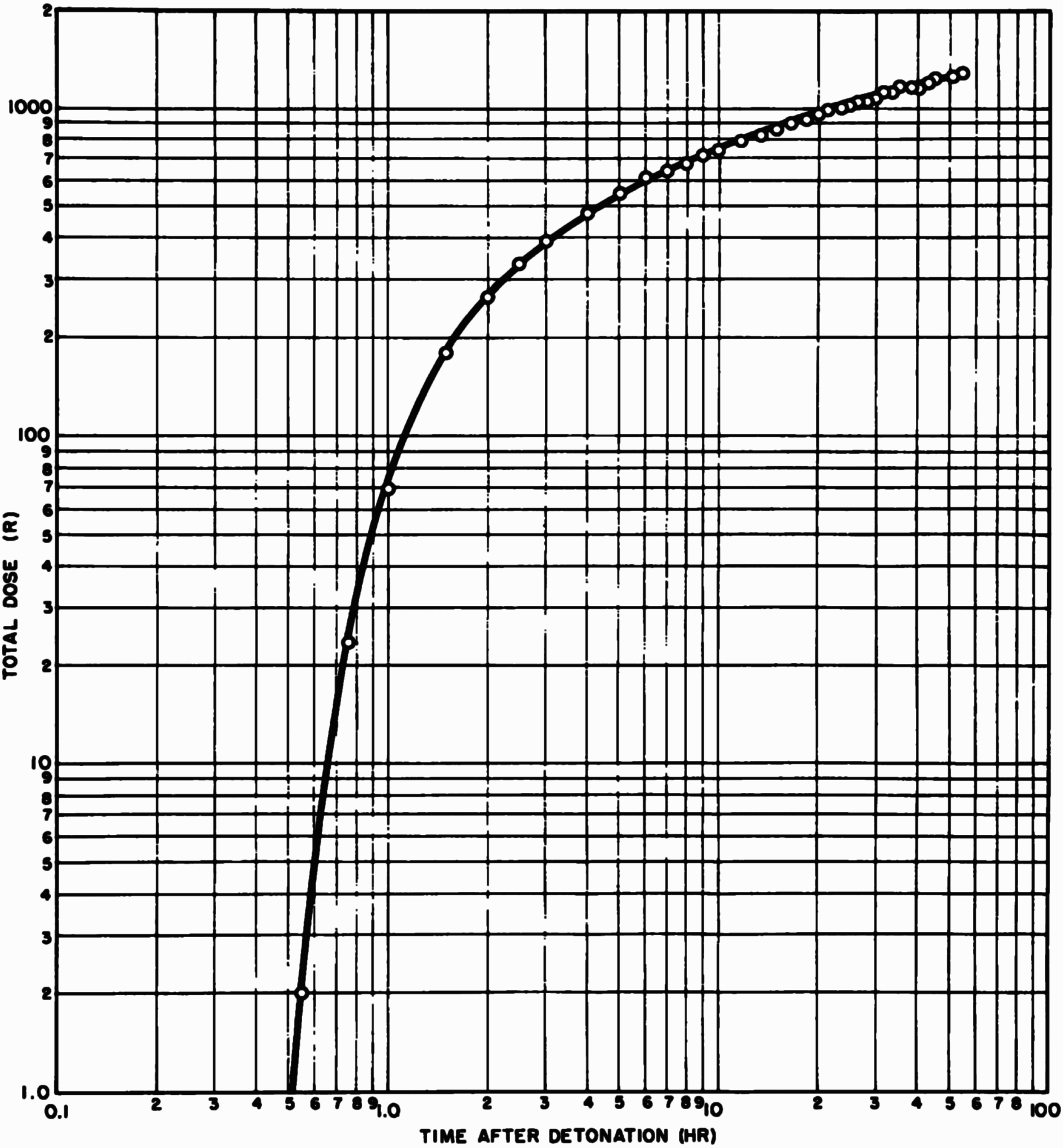

Fig. 5.11 Shot 1, Integrated Gamma Dose, Station 251.03

Bikini (How) Island in Bikini Atoll, which received a land equivalent of about 725 R/hr gamma at 1 hour reference time, according to Figures 2.2 and 6.1.

[redacted]

UNCLASSIFIED

SANITIZED VERSION

TECHNICAL ANALYSIS REPORT - AFSWP NO. 507-SAN

RADIOACTIVE FALL-OUT HAZARDS FROM SURFACE BURSTS OF VERY HIGH YIELD NUCLEAR WEAPONS, Sanitized Version

by

D. C. Borg
L. D. Gates
T. A. Gibson, Jr.
R. W. Paine, Jr.

WEAPONS EFFECTS DIVISION

This Armed Forces Special Weapons Project Technical Analysis Report is a staff study prepared for the Chief, AFSWP on a subject of military interest. The conclusions may be modified as new data become available.

MAY 1954

HEADQUARTERS, ARMED FORCES SPECIAL WEAPONS PROJECT
WASHINGTON 13, D. C.

[redacted]

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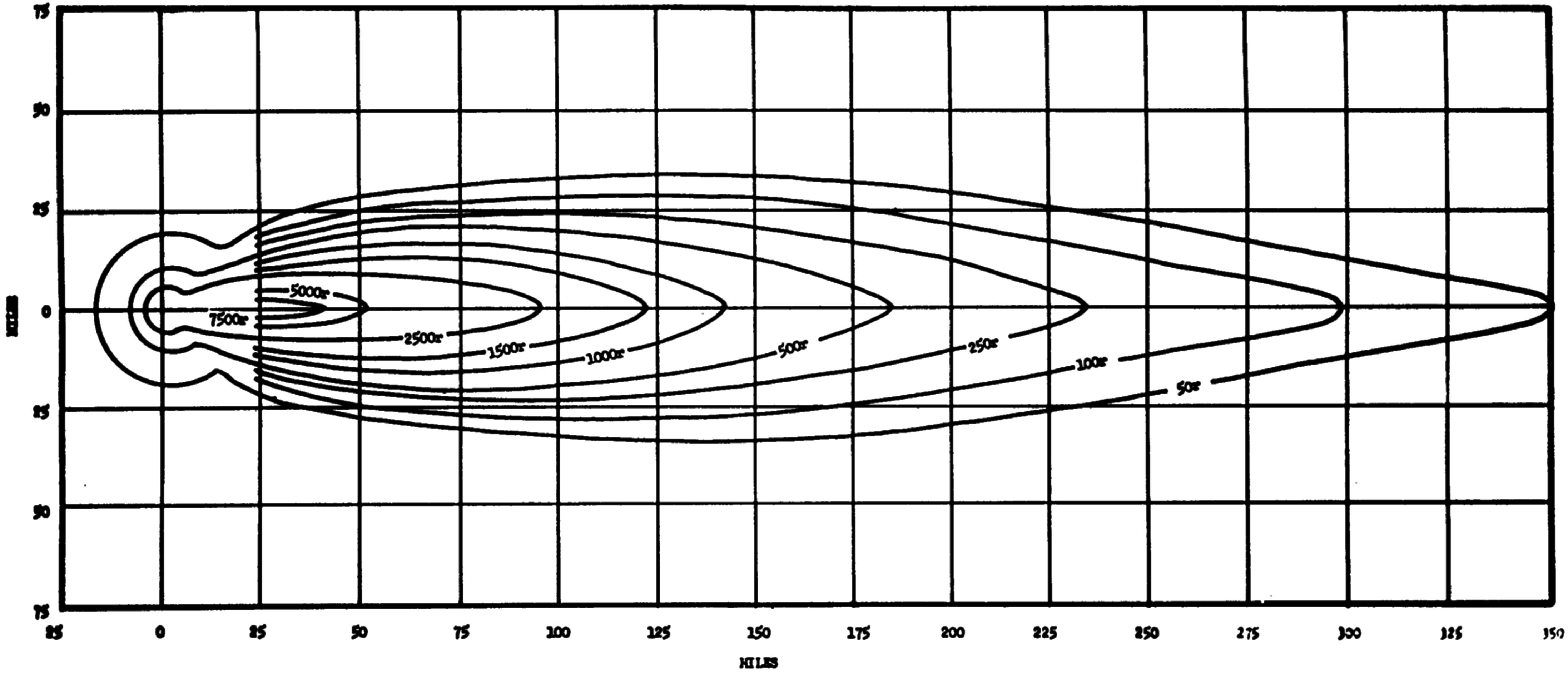
Fig. A TOTAL DOSE FROM TIME OF FALL OUT TO H+50

Idealized Fall-out Contours for a 15 MT Land-surface Burst with a 15 Knot Effective Wind



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The shielding afforded by an ordinary frame house may effectively reduce the size of the hazard areas by a factor of about two, and a basement shelter by a factor of ten or more. Virtually complete protection against the lethal effects of radioactive fall-out can be obtained if personnel have protection equal to or better than that afforded by a simple underground shelter with at least three feet of earth cover, and if they are evacuated after a week or ten days in such a shelter.

One may draw the following conclusions from this analysis:

a. Very large areas, of the order of 5,000 square miles or more, are likely to be contaminated by the detonation of a 15 megaton yield weapon on land surface, in such intensities as to be hazardous to human life.

b. The fact that a large percentage of the radiologically hazardous area will lie outside the range of destructive bomb effects for normal wind conditions, extending up to several hundred miles downwind, makes the radiological fall-out hazard a primary anti-personnel effect.

c. Accurate pre-shot prediction of the location of the hazardous area with respect to the burst point is virtually impossible without extensive wind data at altitudes up to about 100,000 feet, owing to the sensitive wind-dependence of the distribution mechanism.

d. The fall-out contaminant can be expected to decay at such a rate that all but the most highly contaminated areas could be occupied by previously unexposed personnel on a calculated risk

basis within a few days after the contaminating event; and even these highly contaminated areas may then be entered briefly by decontamination teams.

e. Passive defense measures, intelligently applied, can drastically reduce the lethally hazardous areas. A course of action involving the seeking of optimum shelter, followed by evacuation of the contaminated area after a week or ten days, appears to offer the best chance of survival. At the distant downwind areas, as much as 5 to 10 hours after detonation time may be available to take shelter before fall-out commences.

f. Universal use of a simply constructed deep underground shelter, a subway tunnel, or the sub-basement of a large building could eliminate the lethal hazard due to external radiation from fall-out completely, if followed by evacuation from the area when ambient radiation intensities have decayed to levels which will permit this to be done safely.

g. It is of vital importance for individuals in hazardous areas to seek optimum shelter at once, since the dosage received in the first few hours after fall-out has commenced will exceed that received over the rest of a week spent in the contaminated area.

[redacted] [redacted]

Table II

Total Isodose Contour: 500r from Fall-out to H+50 Hours

Yield (MT)	15	1	10	60	* 60
Downwind extent (mi)	180	52	152	340	(307)
Crosswind axis (mi)	40	12	34	70	
GZ circle radius (mi)	11.5	3.85	9.7	21	
GZ circle displacement (mi)	3.5	1.2	3	5.75	
Area (mi^2)	5400	470	3880	17,900	(16,250)
Area of true ellipse (mi^2)	(5650)	(491)	(4055)	(18,700)	

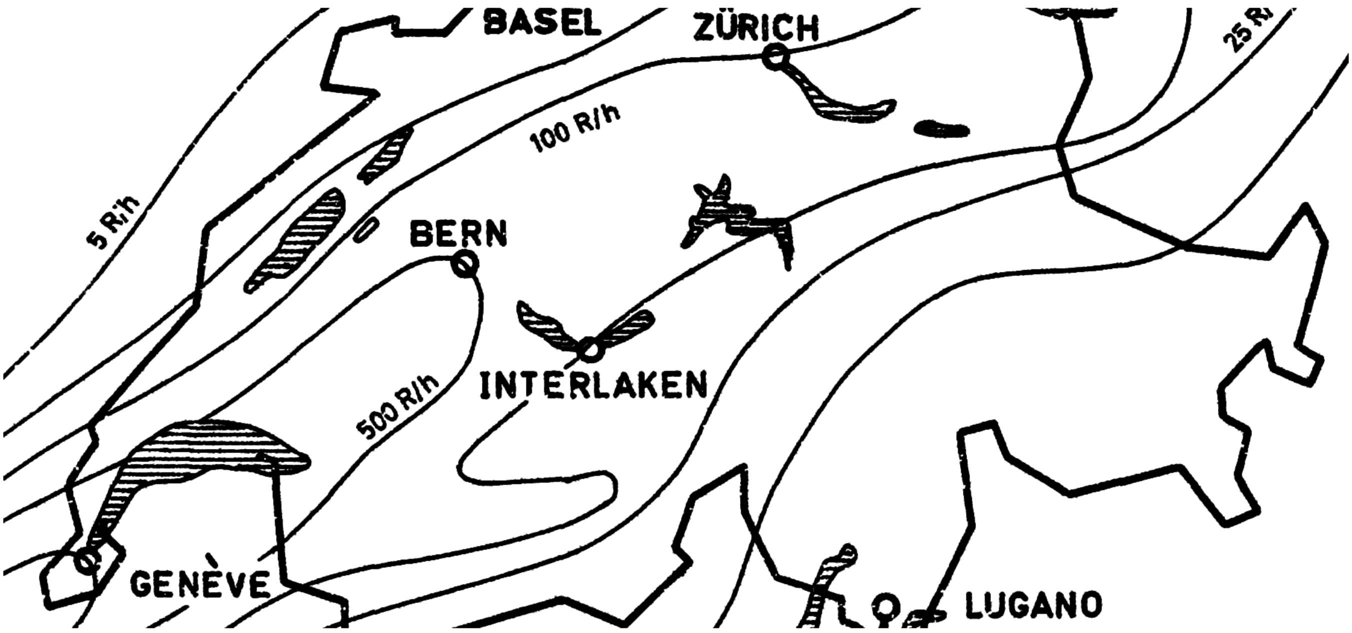
* Using Part D, Chapter II.

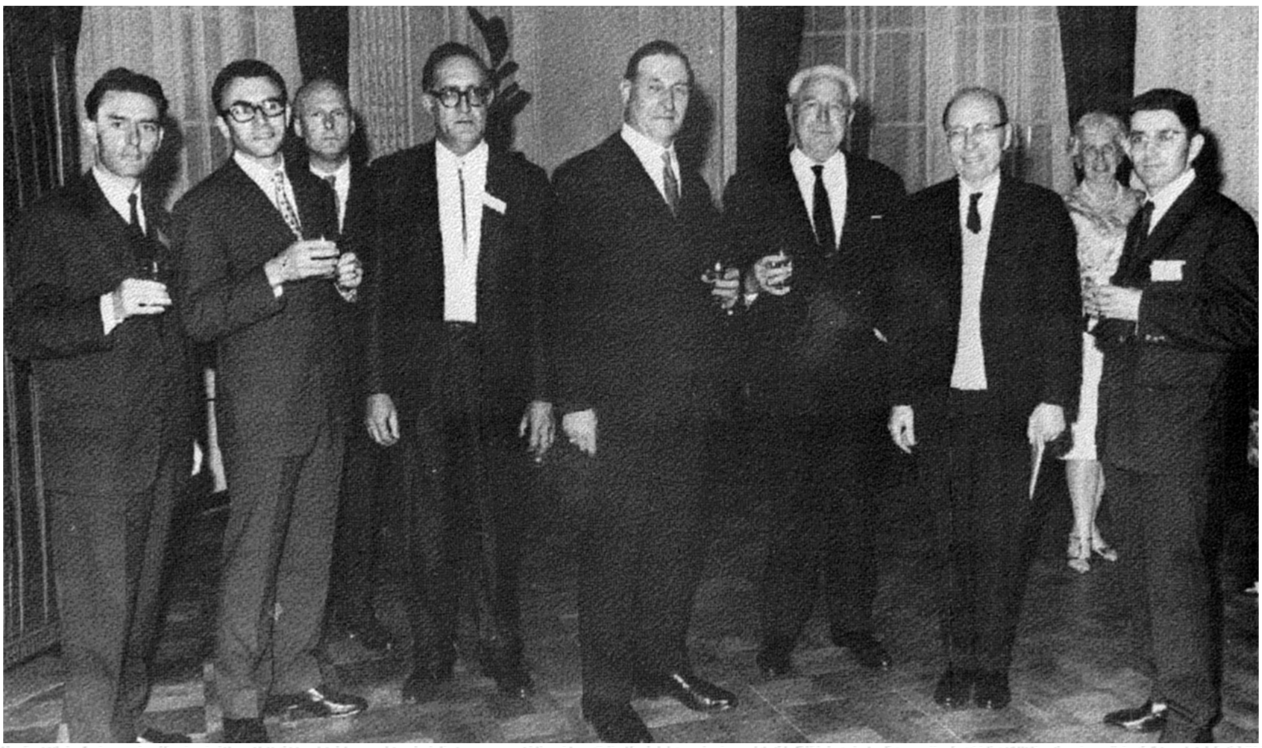
FACHVERBAND FÜR STRAHLENSCHUTZ E.V.

Mitgliedsgesellschaft der International Radiation Protection Association (IRPA)

PROCEEDINGS of a SYMPOSIUM

RADIOLOGICAL PROTECTION OF THE PUBLIC IN A NUCLEAR MASS DISASTER

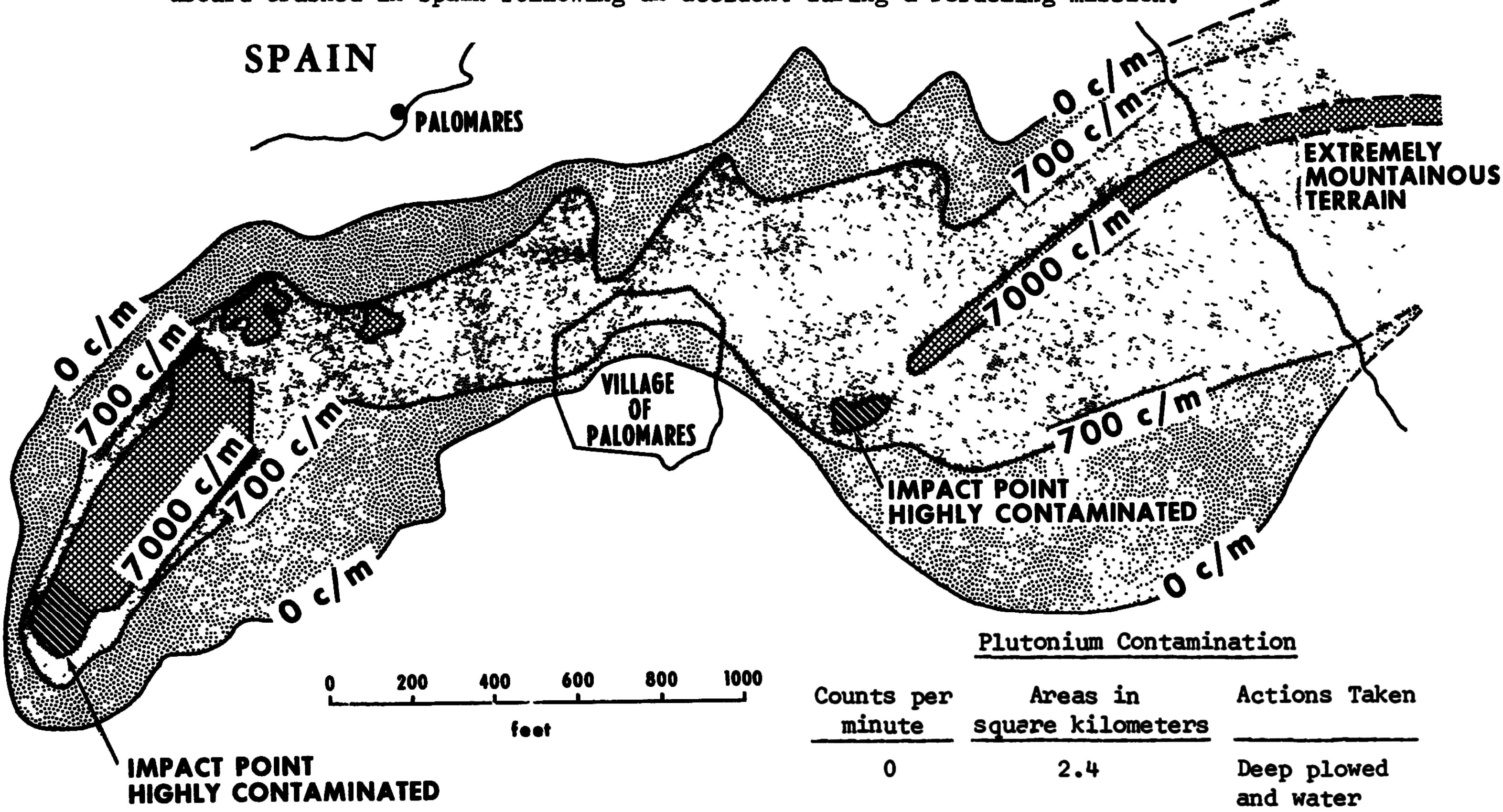




Front row: O. Burkhardt, Administrative Secr. of the Symposium - S. Prêtre, Pres. of "Fachverband für Strahlenschutz" - Dr. C.F. Miller, URS Corp., Burlingame, California - Bundesrat L. von Moos, Member of the Swiss Government, Minister of Justice and Police - W. König, Dir. of the Swiss Federal Office of Civil Defense - Prof. E.P. Wigner, Princeton Univ., Nobel Prize in Physics 1963 - H. Brunner, Scientific Secr. of the Symposium.

INTERLAKEN, SWITZERLAND, 26 MAY–1 JUNE 1968

On January 17, 1966, a B-52 U.S. Air Force aircraft with nuclear bombs aboard crashed in Spain following an accident during a refueling mission.



Plutonium Contamination

Counts per minute	Areas in square kilometers	Actions Taken
0	2.4	Deep plowed and water
700	2.0	(Deep plowed,
7,000	0.17	(watered and (vegetation removed
over 60,000	0.022	Surface scraped

Plutonium quickly oxidizes forming insoluble plutonium oxide.

The potential sources of inhalation of plutonium under these conditions are one, the cloud of radioactive material as it rolls by immediately after the event and, two, resuspension of the plutonium from the ground into the air afterwards. Available data indicate that the first source will probably result in a higher amount of plutonium being deposited in the lungs.[1.]

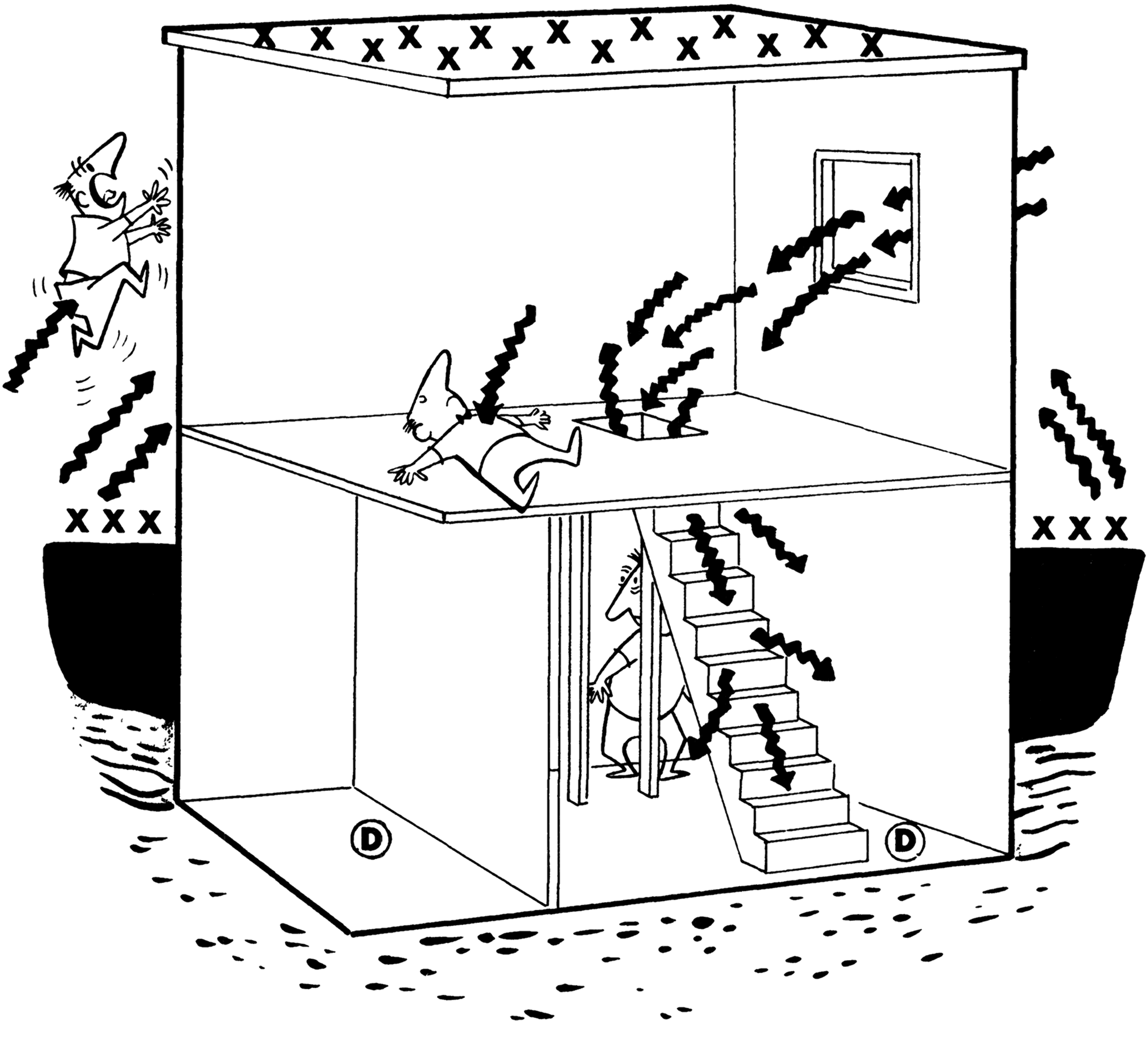
In short, experiments[1., 2.] showed that if a person were exposed to the highest concentration of plutonium in the cloud from such an accident he might receive a total radiation dose to the lungs of about 5 to 10 rem. The second of the major field tests was conducted under inversion meteorological conditions in order to maximize the concentration in the air at ground level.

1. Summary Report, Test Group 57; Report No. ITR-515 (Del.), Shreve, J.D., Jr. April 1958.
2. Operation Roller Coaster 1963. "Biological Studies Associated with a Release of Plutonium." Wilson, Robert and Terry, Jack.

STATUS OF FALLOUT SHIELDING CALCULATIONS IN THE USA

C. Eisenhauer, NBS

In summary, there is a continuing program of experimentation going on to check the accuracy of the present calculations used to predict protection from fallout. However, this program must be accompanied by another which studies the impact of inaccuracies on the various phases of the Civil Defense program. It is not unlikely that there is a range of protection factors for which much greater accuracy is required.



THE NATURE AND BEHAVIOR OF LOCAL FALLOUT

By

Carl F. Miller

THE FORMATION PROCESS

The larger glassy particles, formed from vaporized and melted soil material, are entrained in the fireball before it cools to the melting point of the soil. During this time, the larger melted particles not only collide and coalesce with the smaller liquid soil droplets, but serve as a condensation media for other vaporized condensable fission products. The crystalline particles, entering the fireball after it has cooled to temperatures less than the melting point of the soil material, collect only late-condensing fission product radionuclides on their surfaces in addition to intercepting a few of the small vapor-condensed particles. The late-condensing fission products consist mainly of the volatile elements such as Sb, Te, and I, and the daughter products of rare gases such as Rb and Cs.

The derived specific activity of the local fallout from Shot SMALL BOY, a low-yield device detonated near ground surface at the Nevada Test Site, is shown as a function of particle diameter in Figure 1. The low values of the specific activity for the smaller particles resulted from the unavoidable presence of extraneous local dust particles in the collected samples.

The curve of Figure 1 may be represented by:

$$C = \frac{3.5 \times 10^{18} \left[1 - e^{-6.9 \times 10^{-4} d}\right]}{d}, \quad d = 50 \text{ to } 4{,}000 \text{ microns} \qquad (1)$$

where d is the particle diameter in microns and C is in fissions per gram. The range in d indicates that essentially all of the radioactive particles falling in the local fallout area were greater than 50 microns and that essentially none were found larger than 4,000 microns. The form of Equation 1 and the numerical coefficient values indicate that the gross radionuclide content of the particles is essentially proportional to particle volume or weight for particles with diameters between about 50 and 200 microns. For particles with larger diameters, the radionuclide content becomes increasingly concentrated on the surface of the particles and at diameters of about 2000 microns and larger, the radionuclide content is essentially proportional to

surface area (i.e., to 1/d). The specific activity of the smaller particles would be expected to be larger than the limiting value of Equation 1 and should increase somewhat as the diameter decreases below about 50 microns.

The major significance of the two-stage fallout formation process, aside from the resulting bimodal particle type composition, is that the radionuclides that condense into the liquid droplets in the first stage become immobilized with regard to latter contamination of water and cycling in food chains; but the radionuclides that condense in the second stage on the surfaces of the particles may not be permanently immobilized and do become involved in later biochemical processes.

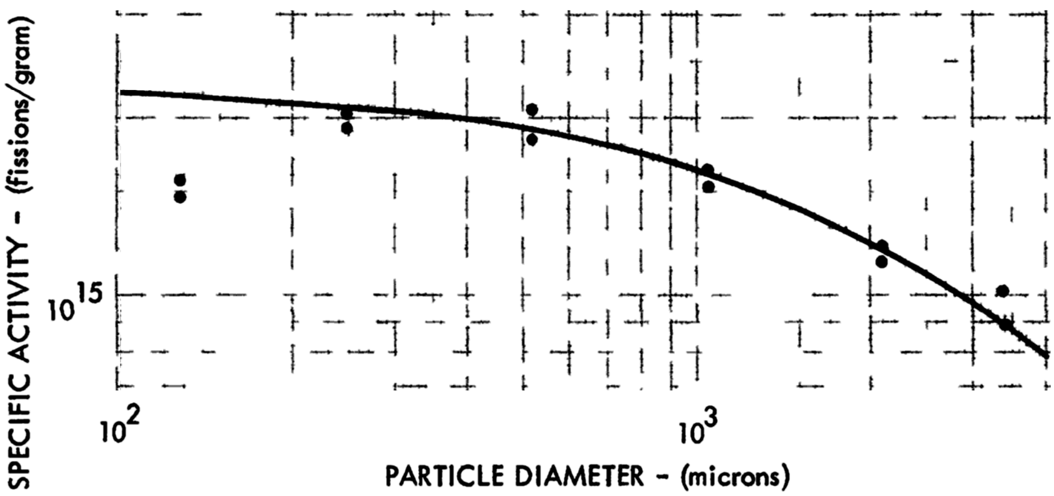


Figure 1. Specific Activity For Shot Small Boy.

Figure 2. Example Representations of Observed Fallout Patterns.

As the fireball cools and rises into the atmosphere, toroidal circulations take place. This circulation apparently concentrates the remaining gaseous radionuclides and smaller particles in the center of the toroid and, due to the downward flow of air at the periphery, accelerates the falling out of the larger particles. Thus, the time of arrival of the largest fallout particles is usually less than is estimated on the basis of free fall from the bottom of the cloud.

BETA RADIATION HAZARDS AND BETA-GAMMA RELATIONSHIPS ASSOCIATED WITH LOCAL FALLOUT

J. D. Teresi*

U. S. Naval Radiological Defense Laboratory
San Francisco, California 94135

Four cases of beta-ray burns of the hands, which occurred during an atomic bomb test at Eniwetok, have been reported by Knowlton et.al.[2] Two of the men received beta ray doses of 5,000 - 10,000 rads, another received 8,000 - 16,000 rads, and the fourth received 3,000 - 4,500 rads. For all but the smallest dose, skin damage was so extensive that grafts were required. There was loss of mobility of some of the fingers. In one case serious ulcers persisted for periods greater than 100 days after the exposure. The effects of the smallest dose were less pronounced; however, the damage persisted for a period greater than 50 days.

Amount of Transepidermal Radiation Required for the Production of Recognizable Transepidermal Injury (Porcine Skin) From Ref. (1)

Isotope	Maximum Beta Energy (Mev)	Surface Dose Required (rep)	Estimated Dose at 0.09-mm Depth (rep)
S-35	0.17	20,000	1200
Y-91	1.53	1,500	1200

2000-4000 rad	Early erythema under 24 hours Skin breakdown in 2 weeks
4000-10,000 rad	Severe erythema in 24 hours Severe skin breakdown in 1-2 weeks
10,000-30,000 rad	Severe erythema in 4 hours Severe skin breakdown in 1-2 weeks
30,000-100,000 rad	Immediate skin blistering (less than 1 day)

The expected beta dose rate at contact in a large field contaminated by fallout was calculated[10] to be 40 times the gamma exposure-rate reading taken at 3 feet. For example if the gamma reading at 3 feet is 100 R/hr, the expected beta dose rate at contact will be 4,000 rads/hr. This is true for a beta-particle to gamma-photon ratio of 1. This ratio is approximately equal to unity for times after a nuclear burst of a few hours to 3 or 4 months. At early times (a few minutes to an hour) the ratio may be as high as 2, in which case the beta dose rate will be 80 times the gamma exposure rate.

The beta doses associated with local fallout contamination of terrain and clothing have also been estimated by Pretre[11] who compared the beta and gamma doses to people exposed to terrain and clothing contaminated with fallout. His calculations were essentially in agreement with those reported in reference 10.

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10. Broido, A., and Teresi, J.D., "Analysis of the Hazards Associated with Radioactive Fallout Material - I. Estimation of γ and β-Doses", Health Physics 5, 63, 1961.

11. Pretre, S., "Importance Biologique Relative des Doses Beta de la Peau Comparees aux Doses Gamma du Corps Entier", Section ABC 33/22 Bulletin ABC No. 7, April 1965.

http://www.osti.go OSTI Identifier: 4822127 Report CONF-680507 (31 October 1969): Radiological Protection of the Public in a Nuclear Mass Disaster, Symposium, Interlaken, Switzerland, 26 May-1 June 1968

BASIC CHARACTERISTICS OF NUCLEAR RADIATION FROM FALLOUT

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Radioactivity may also be produced by neutron interactions within the weapon itself. In many weapons the primary radiation of this type is ^{239}Np (half-life, 2.3 days) produced by the reaction $^{238}U(n,\gamma)$ $^{239}U(\beta)$ ^{239}Np because of the presence of ^{238}U (see pp. 1690-91 of reference 17). The nuclide ^{239}U decays with a half-life of only 23.5 minutes so usually is not observed in significant amounts in fallout measurements.

Other materials besides uranium can be introduced into the regions surrounding the active portions of a nuclear weapon. These materials are then subjected to a tremendous neutron flux density when the weapon is detonated, with the result that many radioactive nuclei are formed. At one time the hazards produced by gamma radiations of a so-called cobalt bomb were discussed extensively. Based on what he considered reasonable assumptions, Dunning[18] calculated the residual-radiation exposure and exposure rate that one could expect from a one megaton nuclear weapon, containing cobalt, that derived half of its energy from fission and half from fusion. His conclusions are that the effect of the cobalt is almost insignificant at very early times but it becomes appreciable after several days. For example, his calculations indicate that one hour after detonation the gamma-ray exposure rate produced by the fission products is about 5.9×10^5 times the exposure rate produced by the ^{60}Co gamma rays, but after 30 days the fission-product exposure rate is only 0.02 times the ^{60}Co exposure rate. An infinite time extrapolation shows the contribution to the total-exposure by fission-product radiations and by ^{60}Co radiations to be approximately equal.

Comparison of Fallout and Fission Product Gamma-Ray Spectra

Cook[19] has compared calculations by Nelms and Cooper[15] of expected gamma-radiation spectra from radioactive fission-product nuclides with measured gamma-ray spectra of fallout samples. These comparisons indicate that there is a reasonably close resemblance between calculation and experiment for photons with energies greater than 290 keV. However, the ^{239}Np radiations in the experimental measurements usually completely obliterate the fission-product radiations in the energy regions between 100 and 290 keV.

(Np-239 and U-237 (in thermonuclear bombs) emit easily shielded soft ~ 0.1 MeV gamma rays.)

Experiments Using Real Fallout Fields

Mather et al.,[56] Huddleston et al.,[57] and Frank[58] have measured the gamma radiation emitted by fallout that resulted from two near-surface bursts at the Nevada Test Site. All three groups used scintillation spectrometers, with NaI(Tl) detectors, to measure pulse height distributions.

The effect of ground roughness has been determined in these experiments by measurements of the direct component of the radiation.

In both cases the effect of ground roughness could be simulated by assuming a plane source covered by a layer of earth. In the area where Mather et al. made their measurements, the layer of earth amounted to a thickness of 0.45 g/cm² plus 106 cm of air, and in the area measured by Frank a thickness of 0.95 g/cm² plus 122 cm of air.

Huddleston et al. compared their dose vs. angle of incidence measurements with a calculation by Spencer[44] to determine the effects of ground roughness. They found angular distributions from measurements made three feet above the surface which, when compared with calculations made by Spencer, are comparable to the radiation expected in air about 40 feet above a planar infinitesimally thin source. Further, they found the distribution over a dry-lake bed to closely approximate Spencer's calculated distribution for an air-equivalent distance of 20 feet, and over a plowed field an air-equivalent distance of between 40 and 60 feet.

The equivalent air thickness reported by Huddleston et al. is somewhat greater (if converted to g/cm²) than the equivalent earth thicknesses reported by Mather et al. and by Frank. The differences may have real significance or they may possibly depend on assumptions made in the calculations. The general conclusions derived from these results are that the use of an equivalent air attenuation to represent the soil attenuation produced by ground roughness effects appears to give results that are in reasonably good agreement with experimental observations.

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18. G. M. Dunning, Health Phys. 4, 52-54 (1960).

19. C. S. Cook, Health Phys. 4, 42-51 (1960).

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USNRDL-TR-645

GROUND ROUGHNESS EFFECTS FOR FALLOUT-CONTAMINATED TERRAIN: COMPARISON OF MEASUREMENTS AND CALCULATIONS

J. M. Ferguson
7 May 1963 29 p. UNCLASSIFIED

The effect of ground roughness on the radiation field above fallout-contaminated ground is studied. At past weapons tests, the dose rate over fallout-contaminated ground has been measured as a function of height and angle. These measurements are compared with calculations of the same quantities for 1.12-hr fission products uniformly distributed on a smooth plane. None of the experiments is detailed enough to lead to firm conclusions about the ground roughness effect. However, the data indicate that the ground roughness effect can be simulated by assuming that the fallout is buried under a thin layer of material. For desert terrain this thickness of material is equivalent to about 25 ± 10 ft of air. At 3 ft above the ground this corresponds to a reduction in dose rate by a factor of 0.6 to 0.7, compared to what would be received over a smooth plane.

THE NATURE OF RADIOACTIVE FALL-OUT AND ITS EFFECTS ON MAN

HEARINGS

BEFORE THE

SPECIAL SUBCOMMITTEE ON RADIATION

OF THE

JOINT COMMITTEE ON ATOMIC ENERGY CONGRESS OF THE UNITED STATES

EIGHTY-FIFTH CONGRESS

FIRST SESSION

ON

THE NATURE OF RADIOACTIVE FALLOUT AND ITS EFFECTS ON MAN

MAY 27, 28, 29, AND JUNE 3, 1957

PART 1

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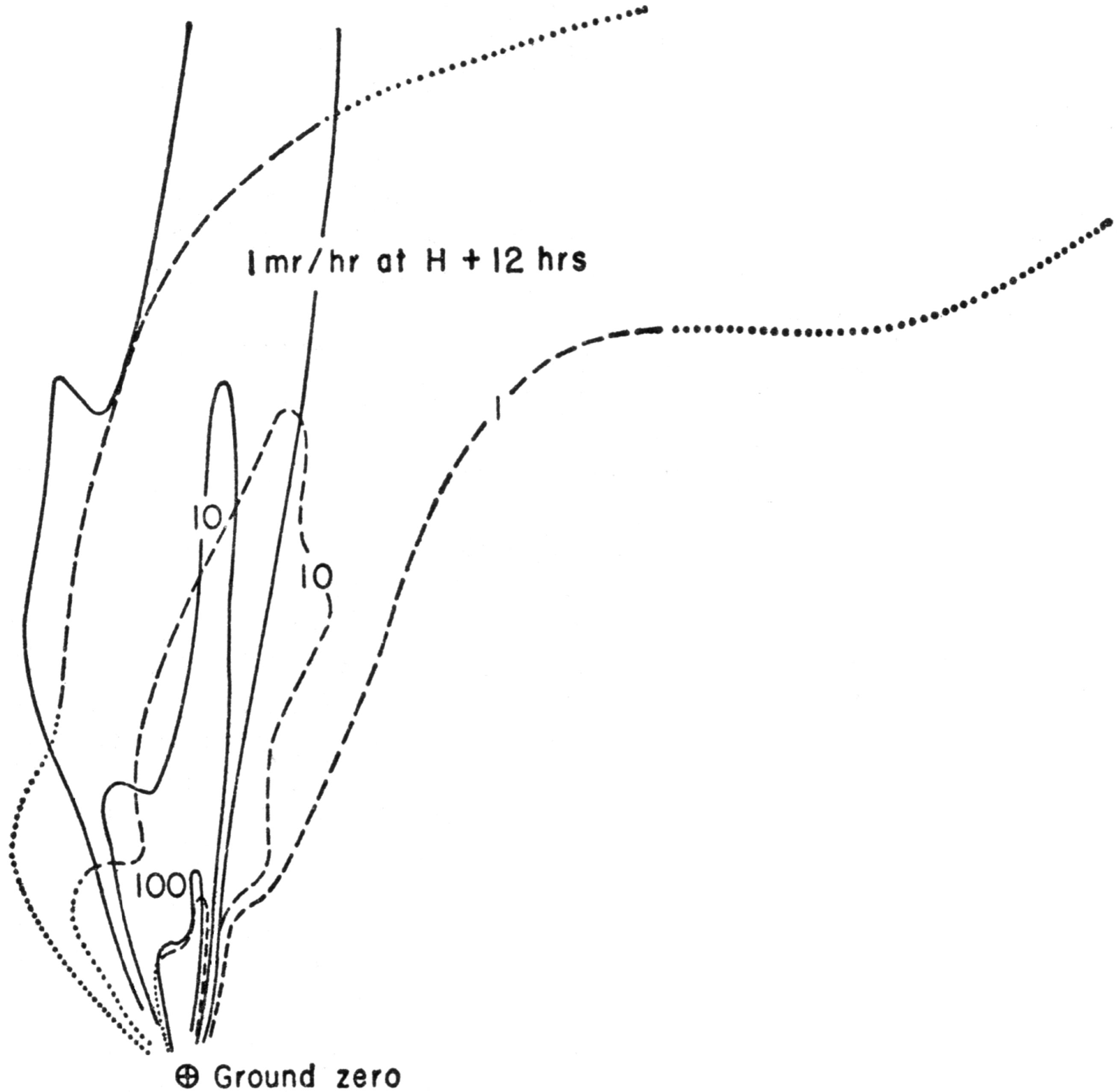

FIGURE 4.—The observed fallout distribution (dashed lines) and the pattern computed by the Weather Bureau using winds predicted at H–2 hours. May 5, 1955.

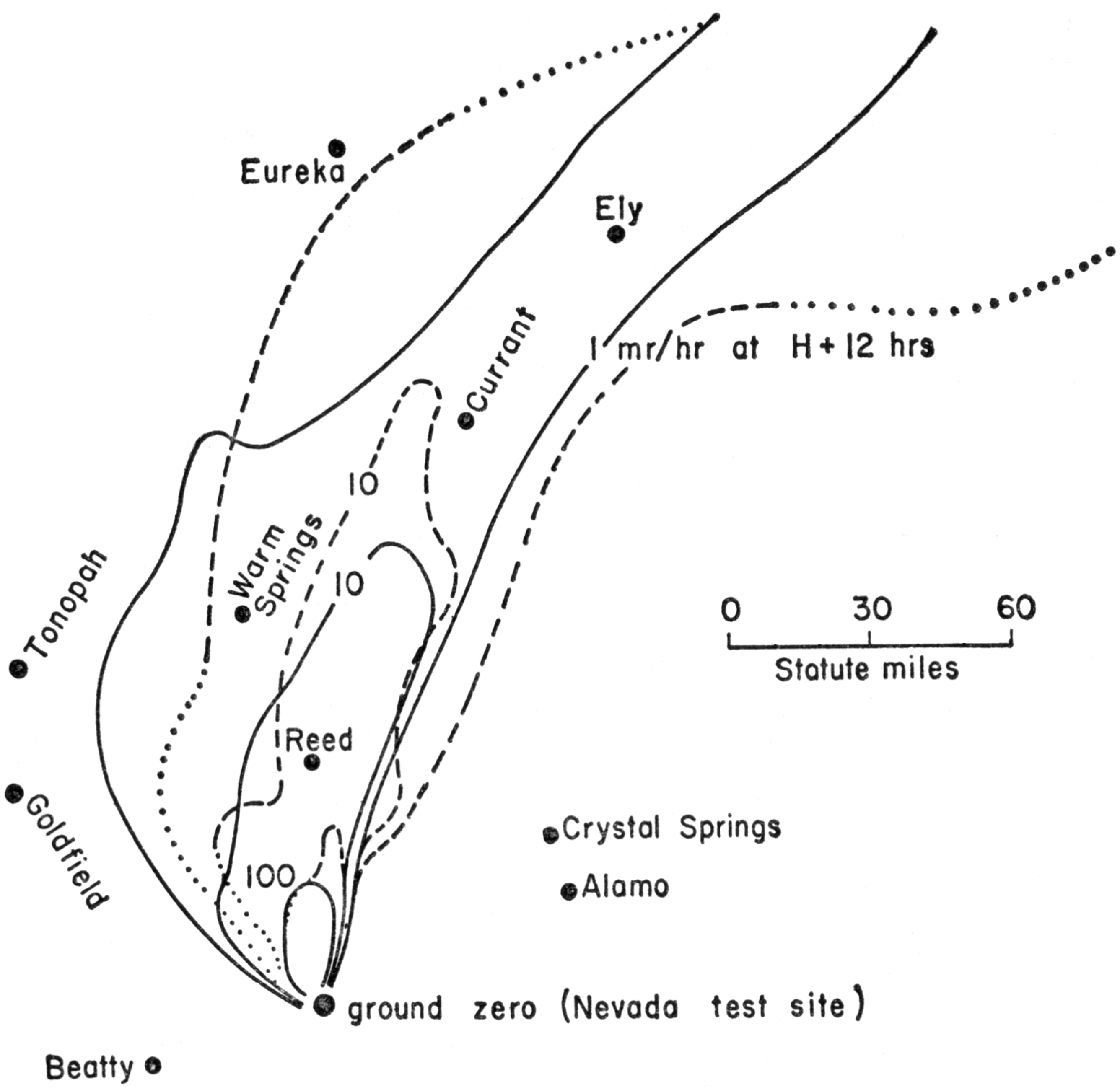

FIGURE 6.—The observed fallout distribution (dashed lines) and the pattern reconstructed by the Weather Bureau using a hand computation with time and space variation of winds (solid lines). May 5, 1955.

MYRON B. HAWKINS (b. 1920), USNR.DL.:

~~tion.~~[1 2 3 4] The contaminability of targets as related to micrometeorology and geometry have not been studied directly, but some information has been derived from experiments with other objectives.[5] As an example, a ship was exposed to fallout from a deep-water detonation.[6 7] The fallout arrived in a 15- to 20-knot wind on the starboard beam.

The following results were obtained:

(*a*) The contamination level (240 readings) on horizontal surfaces varied from 16 percent to 400 percent of the average, i. e., the largest was 25 times higher than the lowest.

(*b*) The gamma radiation level at 3 feet above the deck varied by a factor of 10.

(*c*) The average contamination level for vertical surfaces varied from the average horizontal reading as follows:

1. Forward part of the ship: 40 percent of horizontal average.
2. Aft part of the ship: 20 percent of horizontal average.
3. Lee side: 10 percent of horizontal average.
4. Windward side: approximately equal to horizontal average.

(*d*) Test panels at the stern of the ship had an average contamination level on vertical surfaces three times higher than levels on horizontal surfaces.[8]

Such data cannot be extrapolated or used for predictions without a better understanding of all of the factors involved.

In another example, small buildings and panels of typical building materials were exposed to fallout from land detonations.[4] The contamination levels on typical roofing materials was as much as 300 times higher than that on typical wall panels; or a vertical to horizontal relationship of about 0.3 percent. For panels of the same material, vertical readings were about 10 percent of the horizontal.

The two examples indicate considerable difference in the vertical to horizontal relationships. The characteristics of the fallout appear to have had a considerable influence on this distribution. For instance, the land detonation normally produces a "dry" fallout composed primarily of material from the crater. One can expect masses of 3 to 300 grams of material per square foot to be associated with significant radiation levels at early times. The fallout being a dry powder has little tendency to stick on vertical surfaces.

The fallout from deep-water detonations is largely composed of sea water salts. However, much of the water may evaporate, leaving particles that are damp, semicrystalline masses of a sticky nature. They are capable of sticking to vertical surfaces.

As indicated very little is known of the overall problem of contaminability. It is obvious, however, that two assumptions often made, i. e., ((1) that the fallout is distributed homogeneously on a uniform infinite plane, and (2) that vertical surfaces are not appreciably contaminated) are subject to serious limitations. The ability of a tactical force and/or a civilian population to exploit the variability of the fallout pattern depends upon knowledge we do not have on contaminability.

The contaminability of personnel exposed to the fallout event or working and living in contaminated environments is largely unknown. A study[9] indicating the significance of beta contact hazard to personnel and a requirement for the mass decontamination of personnel, emphasizes the need for additional contaminability information.

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[5] Lee, H., M. B. Hawkins, Some Considerations of the Geometrical Distribution of Fallout Radiation Sources Over Targets, Proceedings of the Shelding Symposium held at USNRDL October 17–18, 1956, vol. II (USNRDL report in preparation), secret.

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COST OF RECLAMATION

Considerable data has been collected regarding the effectiveness of reclamation of targets contaminated by local fallout. The feasibility of applying these methods depends upon the following parameters:

(*a*) The time required to perform the reclamation must be short enough to make an appreciable saving in radiological exposure to mission personnel,

(*b*) The radiation exposure to reclamation personnel must be justified by the saving in exposure of mission personnel,

(*c*) The effort (manpower) and logistics required to reclaim the target must be compatible with the total effort available.

Thus, the cost of reclamation as measured in operating time, effort, radiation exposure, equipment, and supplies is an important determination.

It is impossible to generalize on these quantities for they are influenced by many factors.

The type of fallout, whether it be from a deep water, harbor or land detonation, influences the rate and/or method of decontamination. A deepwater-type fallout can be removed only to an extent of about 60 percent for a firehosing, scrubbing operation on ships,[1] the rate being about 40 square feet per minute. The same decontamination procedure at 6 times the rate of operation on a paved area contaminated by dry-land-type fallout will yield a removal of about 98 percent.[2] To achieve an equivalent removal on the ship, a surface removal technique would be required. Typical rates of operation are about 20 feet per minute for paint stripping [3] and about 7 feet per minute for removing a ⅛-inch thick layer of wood from the flight deck.[4]

The amount (or mass) of fallout on a surface influences the rate, particularly for harbor and dry-type fallout that must be transported over horizontal surfces for considerable distances. The following table shows an example of how the rate decreases with increasing masses of dry fallout for motorized flushing.[2]

Dry fallout gm/ft:[2]	*Motorized flushing rate, ft.²/min.*
10	670
33	650
100	580
330	300

The mass of fallout has no effect on the rate of operation for surface removal or earth moving techniques.

The rate of operation is influence by the surface characteristics of the target, rough surfaces, e. g., wood shingles, requiring longer time than smooth, e. g., metal surfaces. The following table is an example of the influence of surface roughness on rate of operation: [2]

Firehosing of dry contaminant

Material	Effectiveness (percent removed)	Rate (ft²/min/hose)
Corrugated metal	97	65
Composition shingles	95	50
Wood shingles	89	35

The rate of reclamation by earth moving is influenced by soil characteristics. Standard earth moving practice has developed considerable information on this subject.

[1] AFSWP, ITR 1323, preliminary report, Operation Redwing, project 2.9, Standard Recovery Procedure for Tactical Decontamination of Ships. Confidential.

[2] Field Evaluation of Cost and Effectiveness of Basic Decontamination Procedures for Land Target Components, Sartor, J. D., Curtis, H. B., etc., USNRDL–TR in preparation. Unclassified.

[3] Rates approaching 50 square feet per minute are possible if removal of only the surface layer of paint gives the required reduction in radiation intensity.

[4] Proof Testing of AW Ship Countermeasures, Operation Castle, project 6.4 WT-927, Molumphy, Bigger. Confidential.

The degree of mechanization obviously influences rate of operation. The following example compares firehosing rate with that of motor flushing for harbor-type fallout. Also shown are the influence of mechanization on effort and radiation exposure.[2] [5]

Criteria for comparison	Actual performance or cost		
	Firehosing	Motorized flushing	Relative cost FH/MF
1. Operating rate per unit, hr/10⁶ ft²	222	30	7.4
2. Personnel required per unit	5½	2	2.75
3. Effort (direct labor), man-hr/10⁶ ft²	1,210	60	20.0
4. Radiation shielding factor	1.0	0.5	2.0
5. Relative cost in radiation dose	1,210	30	40.0

Target complexity obviously influences rate of operation. For optimum performance, spacings between target components must be large enough to permit mechanized equipment to be used.

A simplified example will help indicate the time, manpower, and basic supplies required for recovery of a target complex. The following criteria are assumed:

(*a*) Target: City of San Francisco.
(*b*) Fallout: Harbor-type at 33 gms/ft².
(*c*) Area to be recovered: About 25 square miles consisting of—
1. All paved areas.
2. All industrial and commercial areas and buildings.
3. 50 percent of the park areas.
4. 10 percent of the residential areas and buildings.
(*d*) Methods: Firehosing and earth moving.

The following table indicates an estimate[5] of the cost of reclaiming these critical areas:

Cost of decontaminating critical areas of San Francisco through use of available firefighting and earth moving equipment for removing slurry contaminant

	Firehosing			Earth moving, land areas	Grand total
	Roofs	Paved surfaces	Subtotal		
1. Time to complete decontamination (24-hour days)	16.8	11.7	28.5	13	----------
2. Direct labor (number of men)	----------	----------	4,000	2,800	6,800
3. Total labor, direct and support (number of men)	----------	----------	6,000	4,900	10,900
4. Total effort (8-hour man-days)	101×10^3	70×10^3	171×10^3	64×10^3	235×10^3
5. Labor cost at $10 per man-day	----------	----------	$\$1.71\times10^6$	$\$0.64\times10^6$	$\$2.35\times10^6$
6. Water required for decontamination (gallons)	362×10^6	314×10^6	676×10^6	----------	----------
7. Fuel required (gallons):					
(*a*) Gasoline	145,000	101,000	246,000	95,000	341,000
(*b*) Diesel fuel	----------	----------	----------	195,000	195,000

As can be seen, the reclamation is feasible in what appears to be a reasonable time. The amount of equipment required is within the capability of existing sources in San Francisco. The manpower is not too excessive considering the numbers of people available. The water requirements are within the capability of the normal supply. Fuel consumption is less than normal daily requirements. The greatest problem would undoubtedly be that of organizing, training, supervising, and controlling 11,000 men.

Automatic decontamination devices such as the washdown system have, as an important advantage, the capability of reclamation at very early times with no expenditure of manpower or radiation exposure. They can be extremely effective (i. e., removal of 90–95 percent) even on sea-water-fallout.[4] However, they do require expenditure of funds before the war begins.

[5] Engineering Approach to Radiological Decontamination, Hawkins, M. B. (Paper to be given ASME semiannual meeting, San Francisco, June 1957.) Unclassified.

ORNL-5037

NUCLEAR WAR SURVIVAL SKILLS

Cresson H. Kearny

Date Published—September 1979

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830

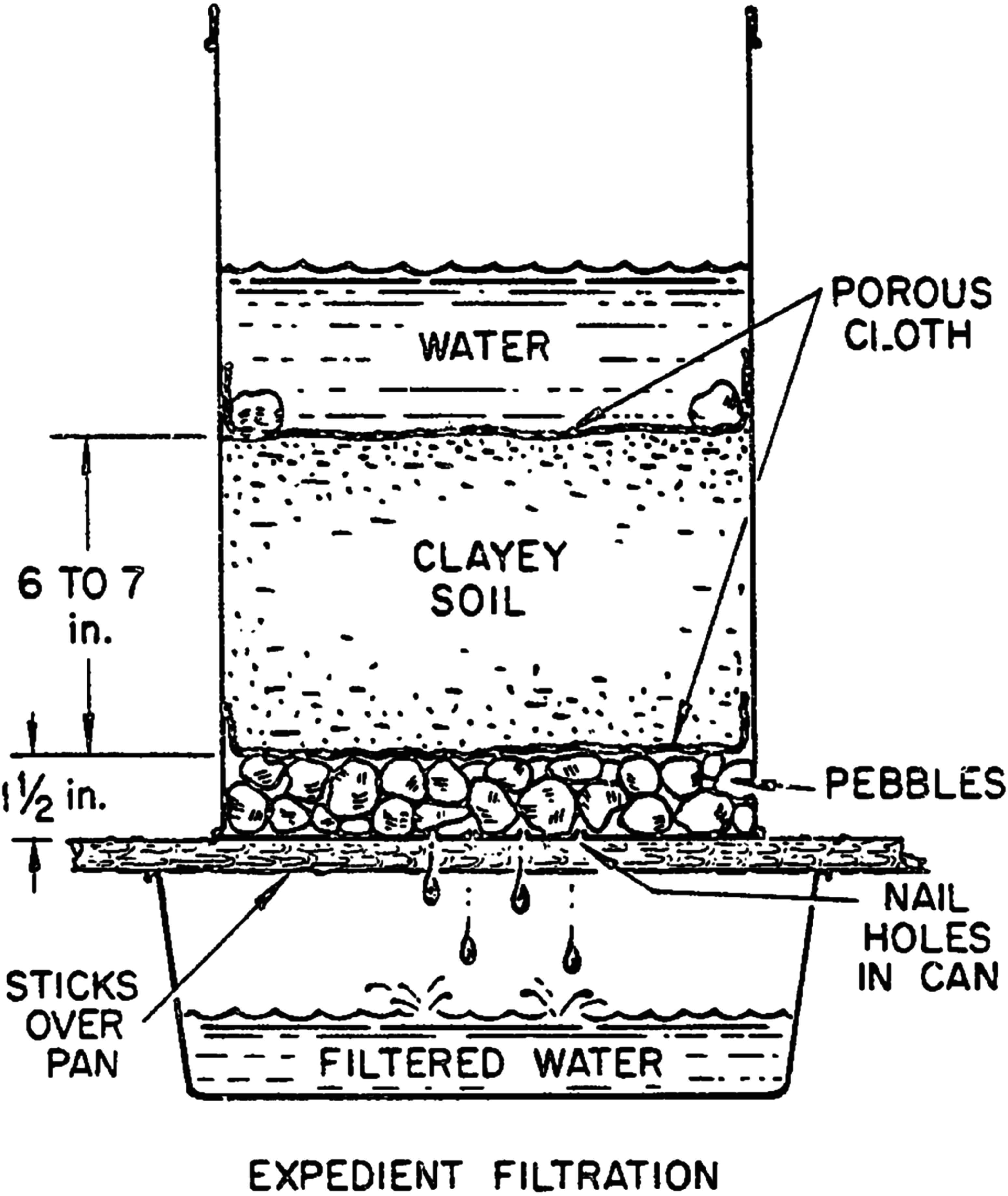

Fig. 8.11. Expedient filter to remove radioactivity from water.

THE NATURE OF RADIOACTIVE FALL-OUT AND ITS EFFECTS ON MAN

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JUNE 4, 5, 6, AND 7, 1957

PART 2

Printed for the use of the Joint Committee on Atomic Energy

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GOVERNMENT PRINTING OFFICE
93299° WASHINGTON : 1957

APPENDIX 10

OAK RIDGE NATIONAL LABORATORY,
Oak Ridge, Tenn., August 21, 1957.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Washington, D. C.

DEAR MR. RAMEY: Enclosed please find a copy of the material concerning topic VIII D of the outline, fallout and water decontamination, requested by Congressman Holifield for the Joint Committee on Atomic Energy Report.

Enclosed is the biographical sketch also requested in your letter of June 19, 1957.

If I can be of any further assistance to you and the committee, please feel free to write.

Thank you.

Very truly yours,

WILLIAM J. LACY,
ERDL Representative at ORNL.

Enclosures: 1. Report on Fallout. 2. Biographical sketch.

Cc: Commanding Officer, Engineer Research and Development Labs, Fort Belvoir, Virginia; Harry N. Lowe, Jr., Chief Sanitary Engineering Branch, Fort Belvoir, Virginia; Dr. Karl Z. Morgan, Director, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

BIOGRAPHICAL SKETCH

William J. Lacy was born in 1928 in Wallingford, Connecticut, attended Lyman Hall High School where he won the prizes in science and chemistry, then he obtained a B. S. degree in 1950 from the University of Connecticut where he majored in Chemistry. He entered graduate school at New York University in September of 1950 and worked as a research associate on an AEC research contract. In May of 1951 he joined the staff at the Engineer Research and Development Labs of Fort Belvoir, Virginia, and immediately was transferred to the Oak Ridge National Laboratory to work on the water decontamination research project.

He has had seven (7) articles published, presented numerous papers and is a member of the American Chemical Society, American Association for the Advancement of Science and the Scientific Research Society of America.

Mr. Lacy is married and has two (2) sons, 2½ and six months, he resides in Oak Ridge, Tennessee.

[Material for Joint Committee on Atomic Energy Topic VIII D]

REMOVAL OF RADIOACTIVE FALLOUT FROM CONTAMINATED WATER SUPPLIES

William J. Lacy, Chemist,* Sanitary Engineering Branch, Engineer Research and Development Labs, Fort Belvoir, Va.

There are two possible sources of radioactive contamination of public water supplies, (1) the result of direct discharge into the environment from reactor processing plants, research center using radioisotopes and others and (2) deposition of radioactive material by fallout or wash-in due to weapon's test activities.

Most of the radioactive materials in item one are in solution, fallout, however, may be in the form of insoluble oxides, and its removal may differ from the removal of ionic material.

Studies have been reported on the subject of fallout in particular areas (1), (2), (3), (4). It was reported that 35 percent of the fallout activity was removed by the Albany, New York, water treatment plant, an alum coagulation, settling and filtration plant. Thomas and his coworkers at Harvard (2) (3) working at the Lawrence, Massachusetts, water plant obtained 80 percent removal by coagulation, settling, and filtration. Bell (4) compared the fallout removal results from Cambridge and Lawrence, Massachusetts, and Rochester, New York, with pilot plant results obtained by Straub (5) (6) who used a simulated bomb blast mixture with an age about one month after detonation.

*On loan to Health Physics Division, Oak Ridge National Lab., Oak Ridge, Tennessee.

The comparison indicated the three treatment plants show much lower removals of fallout than Straub obtained on chemical processed radioactive material even though the same procedure was used in both cases. The U. S. P. H. S. reported the analysis of rain water samples containing fallout showed 50 to 100 percent of the "old" radioactive material to be soluble. However, the soluble fraction dropped to about 30 percent during the weapon's testing period.

For reactor made fission products, or a mixture of commercially available radioisotopes, the efficiency of removal would be a function of the various radioelements comprising the mixture. Results in laboratory studies and pilot plant scale investigations by the author indicates removals of about 70 to 85 percent using either alum and soda ash or ferric chloride and limestone coagulants. A series of studies (7) reported that removals of 99 percent could be obtained using a serial coagualtion procedure including an excess lime-soda ash softening or phosphate coagulation step, provided some clay material was added to remove radiocesium.

Conventional wastes treatment processes include coagulation, settling, and filtration, plus disinfection. Often additional treatment, such as fluoridation, aeration, softening, ion exchange, iron and manganese removal are employed.

During coagulation certain of the dissolved constituents are precipitated as insoluble hydroxides or carried along, scavenged, with the heavy metal hydroxides of alum or iron. Coagulation can have its radioactivity removal increased from about 75 percent to almost 90 percent by the addition of clay for cesium and copper sulfate for radioiodine.

It should be pointed out that different radioisotopes respond differently to removal by coagulation. Other factors to be considered include: (1) Chemical and physical form of the radionuclide, (2) concentration or the radioactive material, and (3) optimum pH of flocculation for the coagulant available and the water under treatment. Investigation by the author (8) indicates increase dosages of chemical generally yielded only slightly higher removals while higher pH usually resulted in proportionately higher removals.

Softening using lime-soda ash is one of the more effective chemical methods for the removal of radiostrontium and barium. However, it is necessary to use excesses quantities, over the stoichiometric dosage, for satisfactory results. Studies at MIT (9) (10) have indicated that the radiostrontium is removed by coprecipitation with the hardness or calcium carbonate in a mixed crystal formation.

Ion exchange is another method used by some municipal water treatment plants. Removal of ionic radionuclides by this process is not only technically possible (11), but very satisfactory. The most effective method employes either a mixed bed principal or separate cation-anion exchange columns. Ion exchange units such as home-type water softeners are very effective for removal of 99+ percent of the radioactive fallout or reactor originated radionuclides from contaminated water. Also ion exchange resins (mixed) can be used with, good results, as slurries for the removal of a vaniety of radioactive contaminants from water solutions (12)

Other methods, such as, the use of clays, powdered metal, charcoal, flotation and various adsorbents all have some merit for the removal of specific radioisotopes or under a given set of condition result in good removals. (13) However, clay seems to have the most practical and over advantage of being (1) available, (2) cheap, (3) effective, (4) simple to use, (5) easy to remove both absorbent and absorber and the radioactive material will not be easily leached once it is attached to the clay particle. Distillation although not a usual municipal water treatment method is used extensively by the military on island bases and where a high quality of water is required. Distillation results in the best single treatment of a contaminated water removing 99.9+ percent. (14) The major objection to distillation as a water treatment procedure is cost.

As indicated by the literature cited most of the above studies have been made on chemically processed, radiochemically pure radioisotopes and not true fallout from a nuclear detonation. Therefore, it was expected that the actual fallout material not being entirely in the same physical and chemical form could not be as readily removed from contaminated water. However, recent tests by the Corps of Engineers at the AEC Nevada Proving Grounds on some very low level fallout indicated (1) close agreement with laboratory results on removal by coagulation and softening using lime-soda ash and precipitation with trisodium phosphate at a high pH, (2) the ion exchange procedures resulted in 99 to 100 percent removal of the bomb fallout material, (3) the material that was not

a true solution could be removed physically and the material in solution treated chemically and (4) radionuclide once adsorbed on clays were not appreciably leached by tap water.

Many other experiments have been made by myself and others, some are still in progress, which have not been cited here. It is felt that this brief general review plus the six tables showing detailed data, will give the committee a review of the field on water decontamination.

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TABLE I.—*Coagulation for removal of radioactivity*

Contaminant	Dosage, p. p. m.	Percent removal	
		$FeCl_3$–$CoCO_3$	Alum-soda ash
Ce^{144}–Pr^{144}	50	99.2	96.1
	100	99.4	96.5
Ba^{140}–La^{140}	50	67.4	58.4
	100	70.7	58.0
Zr^{95}–Nb^{95}	50	98.1	76.4
	100	98.8	78.6
I^{131}	50	45.0	26.3
	100	63.0	35.7
P^{32}	45.7	93.3	94.1
MFP-1 [1]	29–58	60–83.7	----------
MFP-2 [2]	50	70.1	72.6

[1] MFP-1—ORNL waste containing mixed fission products.
[2] MFP-2—Simulated 30-day atomic-bomb blast mixture.

TABLE II.—*Results of lime-soda ash treatment for removal of strontium*

Treatment	Percent removal of activity
Stoichiometric amounts	75.0
20 ppm excess lime-soda ash	77.0
50 ppm excess lime-soda ash	80.1
100 ppm excess lime-soda ash	85.3
150 ppm excess lime-soda ash	97.3
200 ppm excess lime-soda ash	99.4
300 ppm excess lime-soda ash	99.7

TABLE III.—*Ion exchange column for water decontamination*

Run No.	Resin*	Contaminant	Resin capacity gal./ft.^{3}	Percent removal until breakthrough
1	Cation	MFP-1	5,700	71–82
2	Mixed bed	MFP-1	3,150	93–99+
3	Cation	MFP-2	6,000	88–96
4	Mixed bed	MFP-2	2,890	96–99
5	Cation	Zr^{95}–Nb^{95}	6,750	85–88
6	Mixed bed	Zr^{95}–Nb^{95}	2,600	92–97
7	Cation	MFP-3	3,270	85–90
8	Mixed bed	MFP-3	6,150	92–99

*Cation resin was a high capacity nuclear sulfonic acid type and mixed bed was amberlite MB-3.

NOTES

MFP-1—ORNL liquid waste material.
MFP-2—Simulated 30-day atomic-bomb debris.
MFP-3—Three year old dissolved reactor fuel element.

TABLE IV.—*Removal of radioactive contaminants from water—Resin-jar test studies (stirring time, 90 minutes, samples filtered)*

Contaminant	Initial pH	Initial activity c/m/ml	Percent removal mixed ion exchange resin, p. p. m.			
			450	900	1,800	2,700
P^{32}	8.2	5,560	47.4	74.5	96.2	99.8
Cd^{115}	8.0	7,880	37.9	45.6	91.1	99.99
Cs^{137}–Ba^{137}	8.2	8,200	15.1	14.6	69.1	99.99
Zr^{95}–Nb^{95}	8.1	6,700	98.3	98.4	99.2	99.4
I^{131}	7.5	3,200	84.5	93.5	95.6	98.1
Ce^{141}, ^{144}–Pr^{144}	7.9	4,150	98.7	99.2	99.8	99.98
Ba^{140}–La^{140}	7.6	3,490	85.1	94.5	98.8	99.9
FPM-4	8.3	13,600	82.7	90.5	97.3	99.2
FPM-5	2.7	3,400	38.4			

NOTES

FPM-4—Iodine dissolver solution aged 30 days.
FPM-5—Mixed fission product waste containing mainly Cs^{137}–Ba^{137} and Ru^{106}–Rh^{106}.

TABLE V.—*Decontamination of radioactively contaminated water by slurrying with clay*

Contaminant	pH	Clay concentration, p. p. m.	
		1,000	3,000
		Percent removal	
Ru^{106}–Rh^{106}	5.2	50.5	61.5
Zr^{95}–Nb^{95}	7.5	98.0	99.4
Sr^{90}–Y^{90}	7.7	83.4	92.9
I^{131}	7.5	4.9	3.4
$Ce^{141,144}$–Pr^{144}	8.0	99.7	99.9
Ba^{140}–La^{140}	7.8	88.8	94.3
MFP-1	8.8	82.0	86.3
MFP-2	9.0	70.0	72.8
MFP-3	7.7	79.0	83.6

TABLE VI.—*Removal of radioactive material by distillation (60 gallon/hr thermocompression unit)*

Run No.	Contaminant	Activity of feed, d/m/ml	Removal of activity expressed as decontamination factor	Percent
1	MFP-1	22,060	4.10×10^3	99.98
2	MFP-2	97,400	4.97×10^3	99.98
3	MFP-3	31,150	3.59×10^3	99.97
4	MFP-4	62,400	3.52×10^2	99.72
5	Pa^{233}	41,030	2.31×10^3	99.96
6	I^{131}	60,900	7.04×10^2	99.86
7*	MFP-5	38,910	1.09×10^3	99.91
8*	MFP-4	69,700	1.00×10^4	99.99
9*	MFP-1	12,020	1.70×10^4	99.99
10*	I^{131}	45,600	1.28×10^3	99.92
11*	Pa^{233}	25,300	5.80×10^3	99.98

*Glass wool reflux condenser used.

NOTES

MFP-1 was 3-year-old fission product mixture.
MFP-2 was a 2-week-old mixture from disolution of a reactor slug.
MFP-3 was composite sample or ORNL liquid waste.
MFP-4 concentrate from ORNL liquid waste evaporator.
MFP-5 mixture to simulate the material expected 10 days after atomic detonation.

APPENDIX 11

UNITED STATES ATOMIC ENERGY COMMISSION,
Washington 25, D. C., August 20, 1957.

Hon. CHET HOLIFIELD,
Chairman, Special Subcommittee on Radiation of the Joint Committee on Atomic Energy, House of Representatives, Congress of the United States.

DEAR MR. HOLIFIELD: At the suggestion of your Committee, the Division of Biology and Medicine, U. S. Atomic Energy Commission, invited the principal participants in the discussions involving predictions of future skeletal concentrations of strontium 90 in humans which took place at the recent Congressional Hearings on fallout to meet once again in an attempt, insofar as present information permitted, to reduce the degrees of uncertainty in these predictions.

This meeting took place on July 29, 1957 and I am pleased to transmit a summary report of the meeting based on the stenographic transcript and consultation with the principal participants. This report was prepared by Dr. Forrest Western, of the Division of Biology and Medicine. It is my opinion this report honestly and clearly reflects the views of the participant scientists with respect to this problem. This document, then, would appear to reflect the thinking of those scientists who have worked hardest and thought most on the subject of these predictions, and should, therefore, be a useful addition to the text of the very important and

Arguments Against Civil Defense and a Rebuttal

Some of the arguments made against civil defense were parodied as follows in a piece in the Harvard Crimson in 1962:

Recommendations by the Committee for a Sane Navigational Policy:

It has been brought to our attention that certain elements among the passengers and crew favor the installation of lifeboats on this ship. These elements have advanced the excuse that such action would save lives in the event of a maritime disaster such as the ship striking an iceberg. Although we share their concern, we remain unalterably opposed to any consideration of their course of action for the following reasons:

1. This program would lull you into a false sense of security.

2. It would cause undue alarm and destroy your desire to continue your voyage in this ship.

3. It demonstrates a lack of faith in our Captain.

4. The apparent security which lifeboats offer will make our navigators reckless.

5. These proposals will distract our attention from more important things, e.g., building unsinkable ships. They may even lead our builders to false economies and the building of ships which are actually unsafe.

6. In the event of being struck by an iceberg (we will never strike first) the lifeboats would certainly sink along with the ship.

7. If they do not sink, you will only be saved for a worse fate, inevitable death on the open sea.

8. If you should be washed ashore on a desert island, you could not adapt to the hostile environment and would surely die of exposure.

9. If you should be rescued by a passing vessel, you would spend a life of remorse mourning your lost loved ones.

10. The panic caused by a collision with an iceberg would destroy all semblance of civilized human behavior. We shudder at the prospect of one man shooting another for the possession of a lifeboat.

11. Such a catastrophe is too horrible to contemplate. Anyone who does contemplate it obviously advocates it.

A. R. P.

(Air Raid Precautions)

by

J. B. S. HALDANE, F.R.S.

(Co-inventor of 1915 gas masks)

SEPTEMBER
1938

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1938

keyholes and cracks in the wall or between the floor-boards are to be filled with putty or sodden newspaper.

The windows must be specially protected against breakage by blast or splinters.

(Plastic sheets and duct tape for broken windows)

How far are these precautions effective? In 1937 a committee of the Cambridge Scientists' Anti-War Group published a book[1] in which it was stated that no ordinary room is anywhere near gas-proof.

[1] *The Protection of the Public from Aerial Attack.*

Error of Cambridge Scientists' Anti War Group:

The real criticism is as follows. It is unlikely that there would be a lethal concentration of gas out of doors for a long period. The wind carries gas away, and in cities there are vertical air currents even in calm weather. If many tons of bombs could be dropped in the same small area either at once or in succession this would not be so. But given any sort of defence bombs will be dropped more or less at random.

Suppose we had out of doors during 10 minutes a phosgene concentration of one part in 10,000, which would be fatal in a few breaths to people in the street, the concentration inside would never rise as high as $\frac{1}{15}$ of this value[1] if the leakage time were $2\frac{1}{2}$ hours, which is rather low. (Hence protection factor = 15)

[1] Since 10 minutes is $\frac{1}{15}$ of $2\frac{1}{2}$ hours.

Many of the questions which are asked concerning Air Raid Precautions are unanswerable in the form in which they are put. If I am asked "Does any gas mask give complete protection against phosgene" the only literally true answer is "No." One could not live in a room full of pure phosgene in any of them. And one would be killed if a hundred-pound phosgene bomb burst in the room, even when wearing the very best mask. But one would be safe in a phosgene concentration of one part per thousand, of which a single breath would probably kill an unprotected man. Hence in practice such a mask is a very nearly complete protection.

1. NON-PERSISTENT GASES, such as phosgene. They can be dropped in bombs which burst, and suddenly let loose a cloud of gas, which is poisonous when breathed, but which gradually disperses. If there is a wind the dispersal is very quick; in calm, and especially in foggy weather, it is much slower. These gases can penetrate into houses, but very slowly. So even in a badly-constructed house one is enormously safer than in the open air. Even the cheapest type of gas mask, *provided it fits properly and is put on at once*, gives good protection against them (see Chapter IV).

2. PERSISTENT GASES, such as mustard gas. Mustard gas is the vapour of an oily liquid, which I shall call mustard liquid. So far as I know this has not been dropped from aeroplanes in bombs on any great scale. It was used very effectively by the Italians in Abyssinia, who sprayed it in a sort of rain from special sprayers attached to the wings of low-flying aeroplanes.

If the mustard liquid could be sprayed evenly, things would be far more serious. All the outside air of a large town would be poisonous for several days. But this would only be possible if the spraying aeroplanes could fly to and fro over the town in formation, and at a height of not more than 300 feet or so. A fine rain of mustard liquid would probably evaporate on its way to the ground, or blow away, if it were let loose several thousand feet up in the air. Spraying from low-flying aeroplanes was possible in Abyssinia because the Abyssinians had no anti-aircraft guns and no defensive aeroplanes. It would probably not be possible in Britain.

THE HAMBURG DISASTER. Fantastic nonsense has been talked about the possible effects of gas bombs on a town. For example, Lord Halsbury said that a single gas bomb dropped in Piccadilly Circus would kill everyone between the Thames and Regent's Park. Fortunately, although no gas bombs have been dropped in towns in war-time, there are recorded facts[1] which give us an idea of what their effect would be. On Sunday, May 20th, 1928, at about 4.15 p.m., a tank containing 11 tons of phosgene burst in the dock area of Hamburg.

Casualties occurred up to six miles away. In all 300 people were made ill enough to be taken to hospital, and of these ten died. About fifty of the rest were seriously ill. These casualties are remarkably small.

[1] Hegler, *Deutsche Medizinische Wochenschrift*, 1928, p. 1551.

WHY GAS WAS NOT USED IN SPAIN

In view of the terrible stories as to the effects of gas, many people are surprised that it has not been used in Spain. First, why was it not used against the loyalist army? Secondly, why was it not used against towns? The soldiers had respirators after about February 1937, but were not well trained in their use, and often lost them. Very few civilians had any respirators at all.

Gas was not used in the field for several reasons. The main reason is that the number of men and guns per mile was far less than on the fronts in the Great War. Gas is effective if you have a great deal of it,

but the amount needed is enormous. Thus during the night of March 10-11th, 1918, the Germans fired about 150,000 mustard-gas shells into an area of some twenty square miles south-west of Cambrai. If most of the air in a large area is poisoned the effects are serious. But if a few gas shells are fired or a few cylinders let off, the gas soon scatters and ceases to be poisonous, and a man can often run to a gas-free place, even without a mask, before he is poisoned.

Gas was not used against the towns for this reason, and for another, which is very important. Gas only leaks quite slowly into houses, particularly if there are no fires to make a draught, and draw in outside air; and there is very little fuel in loyal Spain.

PANIC

Panic can be a direct cause of death. If too many people crowd into a shelter, especially one with narrow stairs leading to it, they may easily be crushed to death. In January 1918 fourteen people were killed in this way at Bishopsgate Station in London, and sixty-six were killed in a panic in one of the Paris Underground stations as the result of a false gas alarm.

(Bishopsgate Station incident: 28 January 1918)

BACTERIA AND OTHER MICROBES

It is possible that these will be used in some kind of spray or dust. The difficulty is a technical one. It is easy to disperse many solids as smoke. But this needs heat, and cooked bacteria are harmless. Many

bacteria are killed even by drying. And once bacteria are on the ground they generally stay there. Possibly pneumonic plague or some other air-borne disease might be started by a dust-bomb. Cholera bacilli might be dropped in a reservoir. But they would probably be stopped by filters, and even without this would be likely to die before they reached the houses.

A million fleas weigh very little, and could easily be dropped. In theory they could be infected with plague. In practice this would need a staff of hundreds of trained bacteriologists, and huge laboratories. So with other possible means of infection. Some may very well be tried, if only to create a panic, but I would sooner face bacteria than bombs.

Certain pacifist writers are severely to blame for our present terror of air raids. They have given quite exaggerated accounts of what is likely to happen.

So long as civilian populations are unprotected, criminal States will continue to murder the citizens of their weaker neighbours and to blackmail the stronger.

Physical properties of a Gas-cloud. Every student of chemistry learns that a heavy gas such as chlorine can be poured from one vessel into another almost like water, whilst a light gas such as hydrogen rapidly rises. Now all the poisonous gases and vapours used in war are heavier than air, so it is thought that they would inevitably flood cellars and underground shelters, and that on the first floor of a house one would not be safe.

But within a short time it would be mixed with many times its volume of air. Now air containing one part in 10,000 of phosgene is extremely poisonous. But its density exceeds that of air by only one part in 4,000.

APPENDIX II

GAS-MASKS, AND GAS-PROOF BAGS FOR BABIES

THE EARLIEST GAS-MASKS made in 1915, relied on chemical means to stop chlorine, which was the first gas used. A cloth soaked with sodium phenate or various other compounds will stop chlorine on its way through. But it would not stop carbon monoxide, mustard gas, or many other gases. The terrible prospect arose that it would be necessary to devise a new chemical to stop each new gas. There would be a continual series of surprise attacks with different gases, each successful until a remedy was found, and each involving the death of thousands of men.

It is a most fortunate fact that the majority of vapours can be removed from air, not by chemical combination, but by a process called adsorption, which is non-specific. For example lime will stop an acid gas such as carbon dioxide, and woollen cloth soaked in acid will stop an alkaline gas such as ammonia. No single chemical will combine with both.

But charcoal, silica, and various other substances, when properly prepared, will take up vapours of different chemical types. The molecules form a very thin liquid layer on the surface of the adsorbent, as indeed they do on glass or metals. But charcoal is full of pores and has an enormous surface per unit of weight; so it can take up a great deal of gas.

The main characteristic in a vapour which renders it adsorbable is that it should be the vapour of a liquid with a high boiling point. Thus carbon monoxide boils at $-190°$ C, and is hardly adsorbed at all. Phosgene boils at 8° C and is fairly easily adsorbed. Mustard gas boils at 217° C and is very easily adsorbed indeed. This has a lucky consequence. It is quite sure that there are no unknown poisonous gases with a boiling point as low as that of carbon monoxide. For only a substance with very small molecules can have so low a boiling point. And chemists have made all the possible types of very small molecules. It is unlikely that there are any unknown poisonous gases with as low a boiling point as phosgene, though it is just possible. But if there are they will probably be stopped by charcoal. There may very possibly be some vapours of high boiling point more poisonous than mustard gas. But if so I am prepared to bet a thousand to one that charcoal will stop them all.

FINAL REPORT

11 March 1963

Recovery and Decontamination Measures after Biological and Chemical Attack

This report has been reviewed in the Office of Civil Defense and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Office of Civil Defense.

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by

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Washington 7, D. C.

To plan for countermeasures against any weapons one must understand the problem—the nature, the potentials, and the limitations. This research project and the resultant final report were intended to bring together current information most applicable to civil defense. It was particularly intended for those who are responsible for planning preparatory, reclamation and countermeasures effort to minimize the damage from a BW/CW attack.

William J. Lacy
Project Coordinator
Postattack Research

Decontaminants

An important class of decontaminants comprises the common substances or natural influences such as time, air, earth, water, and fire.

Natural Effects

Biological agents are living organisms and tend to die off with time unless they are in a favorable environment with moisture, food, warmth, and other factors necessary for their survival. In addition, most biological organisms are very sensitive to the conditions of temperature and humidity -- and, particularly to the ultra-violet portion of sunlight. Adverse exposure to the elements -- air, sunlight, high temperature, low humidity -- is effective, in fact, against all biological agents except the spore forms of bacterial organisms.

It is generally assumed that in the vegetative form bacteria (as contrasted to the spore form) can persist for less than two hours during daytime and about eighteen hours at night. Since these short-lived bacteria are the most probable agents, outdoor decontamination is usually not called for unless the agent has been identified, either by laboratory tests or by the character of the disease, as one which forms spores or is otherwise known to be persistent.

The persistent, low-volatile, agents such as the liquid nerve agents (V-agents) and the blister gases present the principal chemical decontamination problem. Even these evaporate in time. The speed of evaporation and dissipation is enhanced by higher temperatures and wind. Thus, if it is possible to avoid the area or the use of contaminated objects for a reasonable length of time, decontamination may be unnecessary. Such periods might run from hours to a few days, depending on the degree of contamination and weather conditions. In cold weather the agents will persist for longer periods.

Water

Next to weathering, the most important natural decontaminant is water, used either to remove the agent, with or without soap or detergents to assist, or by boiling. One caution -- water used to wash away contamination becomes contaminated and must be disposed of accordingly. Boiling destroys most chemical agents and all biological agents. When it is feasible, boiling is one of the most generally desirable methods -- particularly for household use by individuals.

Earth and fire, the other natural decontaminants, would have relatively little application in civil defense BW/CW decontamination operations. Earth may be used to cover contamination temporarily to keep it out of contact with people while natural processes either dissipate or destroy the agent. This involves substantial effort with bulldozers and earth-moving equipment and usually is neither practical or necessary.

Chemical Decontaminants

These are preferred when they are available. Chemical decontaminants fall in two classes -- those which destroy or neutralize the agents, and those which simply assist in their removal.

The principal decontaminants which destroy or neutralize are:

- Chlorine-containing materials, such as calcium hypochlorite (HTH) and sodium hypochlorite solutions. Many household disinfectants available under various brand names -- Clorox, Purex, etc. -- are sodium hypochlorite solutions.
- Alkalies, such as caustic soda (lye) and sodium carbonate (washing soda, or soda ash).

The chlorine-containing materials, in proper concentrations, are effective against both biological and chemical agents. As solutions they are used to decontaminate surfaces, as in washing off sealed food containers; for decontaminating cotton fabrics by soaking or addition during the washing process; and for sterilizing water. Hypochlorite solutions have the disadvantage of corroding metals and so must be rinsed off thoroughly.

The hypochlorites -- calcium and sodium -- are the preferred decontaminants for blister gases and liquid nerve agents. For most such applications they are used as solutions but for vertical surfaces or porous surfaces a "whitewash" of calcium hypochlorite (HTH), hydrated lime, and water (called a "slurry") is more effective

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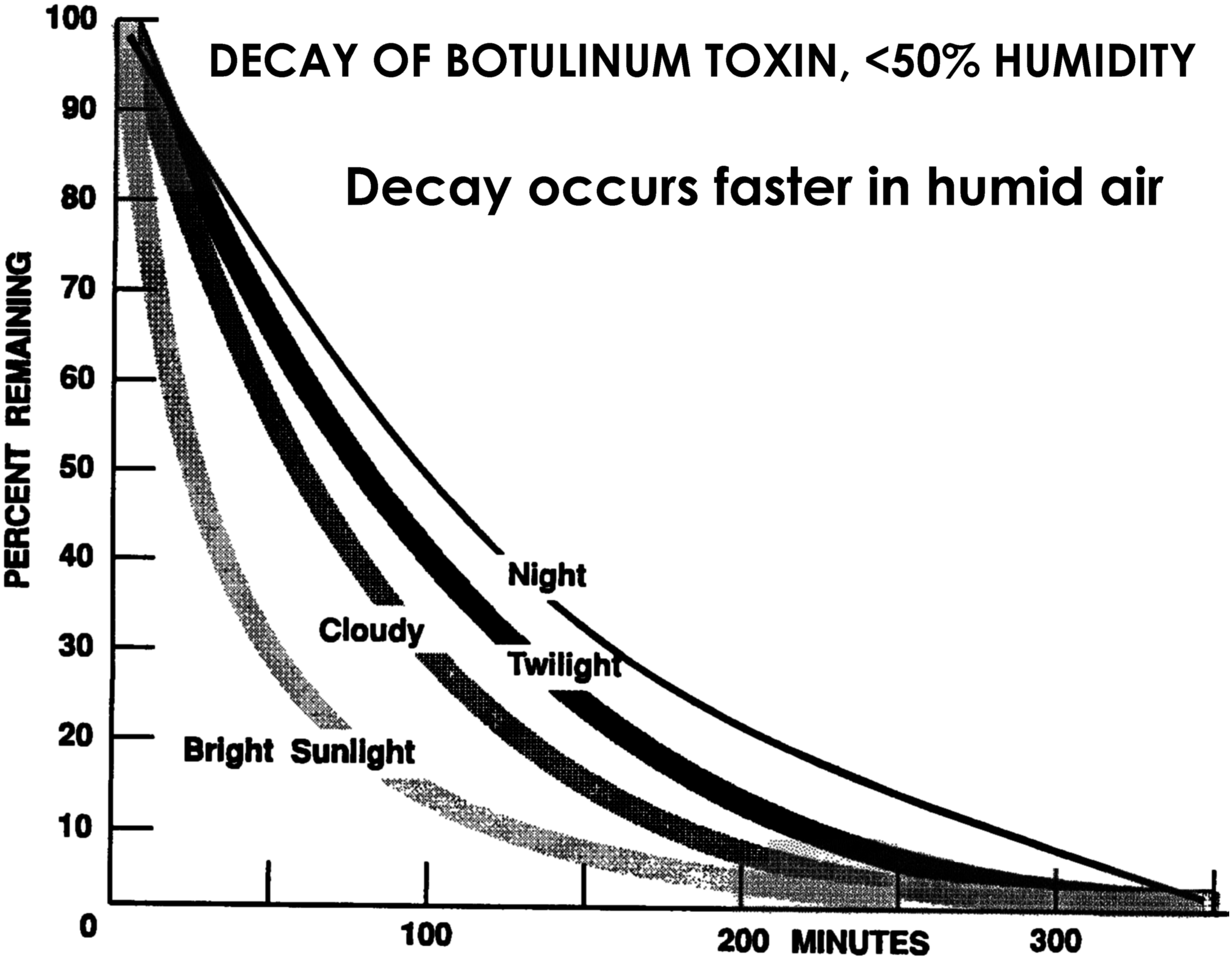
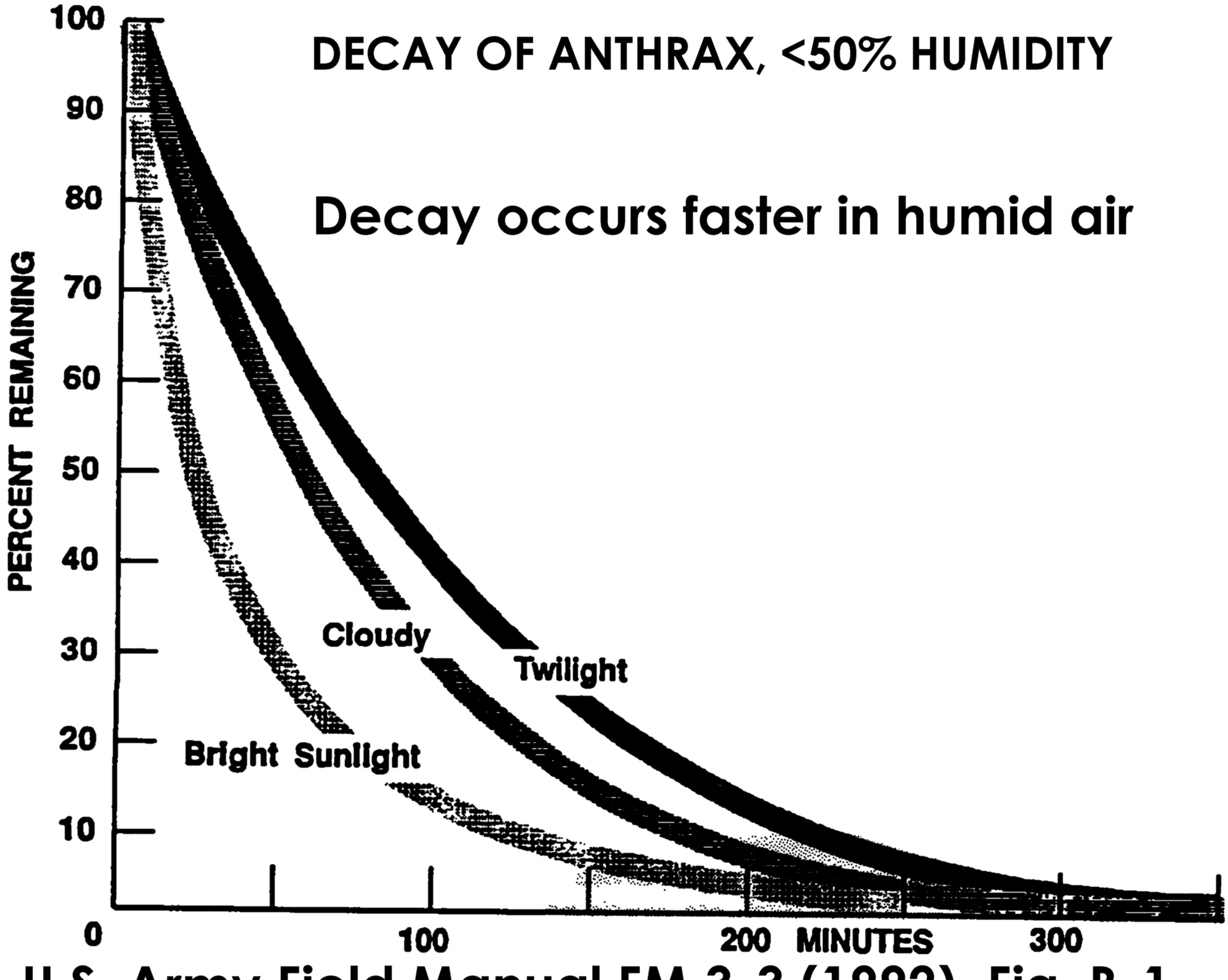


U.S. Army Field Manual FM 3-3 (1992), Fig. B-3.



U.S. Army Field Manual FM 3-3 (1992), Fig. B-1.

Chemical and biological contamination avoidance, FM 3-3 (1992)

10 grams/square meter

TABLE 1-2. Chemical Agent Persistency in Hours on CARC Painted Surfaces.

Temperature		GA/GF[1]	GB[2,3]	GD[2,3]	HD[1]	VX[2,3]
C°	F°					
-30	-22	*	110.34	436.69	**	***
-20	-4	*	45.26	145.63	**	***
-10	14	*	20.09	54.11	**	***
0	32	*	9.44	22.07	**	***
10	50	1.42	4.70	9.78	12	1776
20	68	0.71	2.45	4.64	6.33	634
30	86	0.33	1.35	2.36	2.8	241
40	104	0.25	0.76	1.25	2	102
50	122	0.25	0.44	0.70	1	44
55	131	0.25	0.34	0.51	1	25

NOTE

1 For grassy terrain multiply the number in the chart by 0.4.

2 For grassy terrain multiply the number in the chart by 1.75.

3 For sandy terrain multiply the number in the chart by 4.5.

* Agent persistency time is less than 1 hour.

** Agent is in a frozen state and will not evaporate or decay.

*** Agent persistency time exceeds 2,000 hours.

COMPARATIVE VOLATILITY OF CHEMICAL WARFARE AGENTS

Agent	Volatility (mg/m^3) at 25°C
Hydrogen cyanide (HCN)	1,000,000
Sarin (GB)	22,000
Soman (GD)	3,900
Sulfur mustard	900
Tabun (GA)	610
Cyclosarin (GF)	580
VX	10
VR (“Russian VX”)	9

Data source: US Departments of the Army, Navy, and Air Force. *Potential Military Chemical/Biological Agents and Compounds*. Washington, DC: Headquarters, DA, DN, DAF; December 12, 1990. Field Manual 3-9. Naval Facility Command P-467. Air Force Regulation 355-7.

SIGNS AND SYMPTOMS REPORTED BY TOKYO HOSPITAL WORKERS TREATING VICTIMS OF SARIN SUBWAY ATTACKS*

Symptom	Number/percentage of the 15 physicians who treated patients at UH		Number/percentage of 472 care providers reporting symptoms at SLI	
Dim vision	11	73%	66	14%
Rhinorrhea	8	53%	No information	
Dyspnea (chest tightness)	4	27%	25	5.3%
Cough	2	13%	No information	
Headache	No information		52	11%
Throat pain	No information		39	8.3%
Nausea	No information		14	3.0%
Dizziness	No information		12	2.5%
Nose pain	No information		6	1.9%

*Data reflect reported survey of self-reported symptomatology of physicians at the University Hospital of Metropolitan Japan emergency department and all hospital workers at Saint Luke's International Hospital exposed to sarin vapors from victims of the Tokyo subway attack.

SLI: Saint Luke's International Hospital

UH: University Hospital

Data sources: (1) Nozaki H, Hori S, Shinozawa Y, et al. Secondary exposure of medical staff to sarin vapor in the emergency room. *Intensive Care Med*. 1995;21:1032-1035. (2) Okumura T, Suzuki K, Fukuda A, et al. The Tokyo subway sarin attack: disaster management, Part 1: community emergency response. *Acad Emerg Med*. 1998;5:613-617. (3) Okumura T, Suzuki K, Fukuda A, et al. The Tokyo subway sarin attack: disaster management, Part 2: Hospital response. *Acad Emerg Med*. 1998;5:618-624.

TABLE 21-3

MANAGEMENT OF MILD TO MODERATE NERVE AGENT EXPOSURES

		Management			
		Antidotes*		Benzodiazepines (if neurological signs)	
Nerve Agents	**Symptoms**	**Age**	**Dose**	**Age**	**Dose**
• Tabun • Sarin • Cyclosarin • Soman • VX	• Localized sweating • Muscle fasciculations • Nausea • Vomiting • Weakness/floppiness • Dyspnea • Constricted pupils and blurred vision • Rhinorrhea • Excessive tears • Excessive salivation • Chest tightness • Stomach cramps • Tachycardia or bradycardia	Neonates and infants up to 6 months old	**Atropine** 0.05 mg/kg IM/IV/IO to max 4 mg or 0.25 mg AtroPen† and **2-PAM** 15 mg/kg IM or IV slowly to max 2 g/hr	Neonates	**Diazepam** 0.1–0.3 mg/kg/dose IV to a max dose of 2 mg, or **Lorazepam** 0.05 mg/kg slow IV
		Young children (6 months old–4 yrs old)	**Atropine** 0.05 mg/kg IM/IV/IO to max 4 mg or 0.5 mg AtroPen and **2-PAM** 25 mg/kg IM or IV slowly to max 2 g/hr	Young children (30 days old–5 yrs old)	**Diazepam** 0.05–0.3 mg/kg IV to a max of 5 mg/dose or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg
				Children (≥ 5 yrs old)	**Diazepam** 0.05–0.3 mg/kg IV to a max of 10 mg/dose or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg
		Older children (4–10 yrs old)	**Atropine** 0.05 mg/kg IV/IM/IO to max 4 mg or 1 mg AtroPen and **2-PAM** 25–50 mg/kg IM or IV slowly to max 2 g/hr	Adolescents and adults	**Diazepam** 5–10 mg up to 30 mg in 8 hr period or **Lorazepam** 0.07 mg/kg slow IV not to exceed 4 mg
		Adolescents (≥ 10 yrs old) and adults	**Atropine** 0.05 mg/kg IV/IM/IO to max 4 mg or 2 mg AtroPen and **2-PAM** 25–50 mg/kg IM or IV slowly to max 2 g/hr		

2-PAM: 2-pralidoxime
IM: intramuscular
IO: intraosseous
IV: intraveneous
PDH: Pediatrics Dosage Handbook
*In general, pralidoxime should be administered as soon as possible, no longer than 36 hours after the termination of exposure. Pralidoxime can be diluted to 300 mg/mL for ease of intramuscular administration. Maintenance infusion of 2-PAM at 10–20 mg/kg/hr (max 2 g/hr) has been described. Repeat atropine as needed every 5–10 minutes until pulmonary resistance improves, secretions resolve, or dyspnea decreases in a conscious patient. Hypoxia must be corrected as soon as possible.
†Meridian Medical Technologies Inc, Bristol, Tenn.
Data sources: (1) Rotenberg JS, Newmark J. Nerve agent attacks on children: diagnosis and management. *Pediatrics*. 2003;112:648–658. (2) Pralidoxime [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2002. (3) AtropPen (atropine autoinjector) [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2004. (4) Henretig FM, Cieslak TJ, Eitzen Jr EM. Medical progress: biological and chemical terrorism. *J Pediatr*. 2002;141(3):311–326. (5) Taketomo CK, Hodding JH, Kraus DM. *American Pharmacists Association: Pediatric Dosage Handbook*. 13th ed. Hudson, Ohio; Lexi-Comp Inc: 2006.

TABLE 21-4

MANAGEMENT OF SEVERE NERVE AGENT EXPOSURE

		Management			
		Antidotes*		Benzodiazepines (if neurological signs)	
Nerve Agents	Severe Symptoms	Age	Dose	Age	Dose
• Tabun • Sarin • Cyclosarin • Soman • VX	• Convulsions • Loss of consciousness • Apnea • Flaccid paralysis • Cardio-pulmonary arrest • Strange and confused behavior • Severe difficulty breathing • Involuntary urination and defecation	Neonates and infants up to 6 months old	**Atropine** 0.1 mg/kg IM/IV/IO or 3 doses of 0.25mg AtroPen† (administer in rapid succession) and **2-PAM** 25 mg/kg IM or IV slowly, or 1 Mark I† kit (atropine and 2-PAM) if no other options exist	Neonates	**Diazepam** 0.1–0.3 mg/kg/dose IV to a max dose of 2 mg, or **Lorazepam** 0.05 mg/kg slow IV
				Young children (30 days old–5 yrs and adults	**Diazepam** 0.05–0.3 mg/kg IV to a max of 5 mg/dose, or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg
		Young children (6 months old–4 yrs old)	**Atropine** 0.1 mg/kg IV/IM/IO or 3 doses of 0.5mg AtroPen (administer in rapid succession) and **2-PAM** 25–50 mg/kg IM or IV slowly, or 1 Mark I kit (atropine and 2-PAM) if no other options exist	Children (≥ 5 yrs old)	**Diazepam** 0.05-0.3 mg/kg IV to a max of 10 mg/dose, or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg
				Adolescents and adults	**Diazepam** 5–10 mg up to 30 mg in 8-hr period, or **Lorazepam** 0.07 mg/kg slow IV not to exceed 4 mg
		Older children (4–10 yrs old)	**Atropine** 0.1 mg/kg IV/IM/IO or 3 doses of 1mg AtroPen (administer in rapid succession) and **2-PAM** 25–50 mg/kg IM or IV slowly, 1 Mark I kit (atropine and 2-PAM) up to age 7, 2 Mark I kits for ages > 7–10 yrs		
		Adolescents (≥ 10 yrs old) and adults	**Atropine** 6 mg IM or 3 doses of 2 mg AtroPen (administer in rapid succession) and **2-PAM** 1800 mg IV/IM/IO, or 2 Mark I kits (atropine and 2-PAM) up to age 14, 3 Mark I kits for ages ≥ 14 yrs		

IM: intramuscular
IO: intraosseous
IV: intravenous

*In general, pralidoxime should be administered as soon as possible, no longer than 36 hours after the termination of exposure. Pralidoxime can be diluted to 300 mg/mL for ease of intramuscular administration. Maintenance infusion of 2-PAM at 10–20 mg/kg/hr (max 2 g/hr) has been described. Repeat atropine as needed every 5–10 min until pulmonary resistance improves, secretions resolve, or dyspnea decreases in a conscious patient. Hypoxia must be corrected as soon as possible. †Meridian Medical Technologies Inc, Bristol, Tenn.

Data sources: (1) Rotenberg JS, Newmark J. Nerve agent attacks on children: diagnosis and management. *Pediatrics*. 2003;112:648–658. (2) Pralidoxime [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2002. (3) AtroPen (atropine autoinjector) [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2004. (4) Henretig FM, Cieslak TJ, Eitzen Jr EM. Medical progress: biological and chemical terrorism. *J Pediatr*. 2002;141(3):311–326. (5) Taketomo CK, Hodding JH, Kraus DM. *American Pharmacists Association: Pediatric Dosage Handbook*. 13th ed. Hudson, Ohio: Lexi-Comp Inc; 2006.

FM 100-30

NUCLEAR OPERATIONS

Headquarters, Department of the Army

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Field Manual
100-30

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, DC, 29 October 1996

NUCLEAR OPERATIONS

CONTENTS

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PREFACE

In the past, Soviet-styled armored echeloned formations were the primary threat to the United States (US). In response to this threat the US designed and stockpiled tactical nuclear weapons. Today's threats consist of regional instabilities and the proliferation of weapons of mass destruction (WMD). However, the US, as well as many other nations, actively pursues a policy of nonproliferation. Despite this, the number of nations who have, or are developing, nuclear weapons continues to grow. Therefore, the US may some day find itself confronted by an opponent who possesses nuclear weapons. Because of the continuing reduction in the size of US military forces, the US could also find itself opposed by an overwhelming conventional threat. Either scenario could lead to the use of nuclear weapons. Therefore, the US must concern itself with countering the proliferation of weapons of mass destruction.

Despite the continuing drawdown of US military forces, the current national military strategy includes fighting and winning two near-simultaneous regional wars with conventional forces. Any US threat of employing nuclear weapons is to deter a potential adversary's use of such weapons. If deterrence fails. the goal is to end hostilities on terms acceptable, at the lowest level of conflict, to the US and its allies. However, the US unilaterally reserves the right to use nuclear weapons if necessary. Use would be restricted, of course, with tight limits on the area and time of use. This would allow the belligerent to recognize the "signal" of limited response and to react accordingly.

The Army describes battlefield nuclear warfare (BNW) in terms of being able to conduct continuous combat operations in a nuclear environment. The presence of any nuclear-capable system, before, during, or after nuclear-weapons employment by either friendly or enemy forces, creates a nuclear environment. The implications of their very presence creates the nuclear environment.

Before 1991, the US Army had custody of tactical nuclear weapons which were to be employed, on Presidential release, by organic Army field artillery units. In September 1991, the Presidential Nuclear Initiative (PNI) removed the organic nuclear responsibility from the US Army. Today the Army neither has custody of nuclear weapons nor do corps and divisions employ them. The US Air Force or the US Navy are now responsible for delivery of nuclear weapons in support of Army operations. The Army retains its role in nominating nuclear targets and is also responsible for nuclear force protection.

This manual establishes Army doctrine for operations in a nuclear environment and details the doctrine for integrating nuclear considerations into all other aspects of the battlefield. It also describes the Army's role in nominating targets at corps and above levels and protecting the force from the effects of nuclear weapons detonation.

Nuclear operations may occur at strategic, operational, and tactical levels of war. Nuclear employment in a theater of operations has theater strategic, operational, and tactical results; execution has national strategic implications. The corps' role is to function at either the tactical or operational levels of war. At the tactical level, the corps accomplishes missions as Field Manual (FM) 100-15 describes. At the operational level, when directed and augmented, the corps functions as either the Army force (ARFOR), the joint force land component command (JFLCC), or a joint task force (JTF). By viewing the corps in its many possible roles, the reader can also discern nuclear procedures for echelons above corps (EAC) and joint missions.

This manual can help educate and train commanders and staffs at corps and operational levels in nuclear operations and educate and train divisions in nuclear force protection. It is used with Joint Publications (JP) 3-12.1, 3 -12.2 (SRD), or 3-12.3, and serves as the bridge between joint and

DETERRENCE

Although the US military force's overriding mission is to deter war, especially nuclear war, the intent behind the 1991 Presidential Nuclear Initiative (PNI) was to enhance national security through arms reduction while preserving the capability to regenerate selected forces if required. Recent arms control agreements and unilateral initiatives provide for real reductions in the arsenals of nuclear powers. However, even with the most optimistic outlook, the sheer number of remaining weapons is formidable. An increasing number of potentially hostile states are developing or have the capability to develop weapons of mass destruction. Therefore, the US must maintain a modem, reliable, and fully capable strategic deterrent as its number one defense priority.

Deterrence is the product of a nation's military capabilities and that nation's willingness to use those capabilities. The US' policy is to terminate conflict at the lowest possible level of violence consistent with national and allied interests. The ability to conduct operational- and tactical-level nuclear activities enhances US deterrent policy.

The potential employment of nuclear weapons at theater level, when combined with the means and resolve to use them, makes the prospects of conflict more dangerous and the outcome more difficult to predict. The US' position is that it can achieve deterrence if any potential enemy believes the outcome of nuclear war to be so uncertain, and the conflict so debilitating, that he will have no incentive to initiate a nuclear attack. The resulting uncertainty reduces a potential aggressor's willingness to risk escalation by initiating conflict.

At the same time, a credible defensive capability, which would include the threat of employing nuclear weapons, could bolster the resolve of allies to resist an adversary's attempts at political coercion. For example, the US' capability of responding to biological and chemical attacks with nuclear weapons would likely reduce or eliminate such attacks.

Nuclear weapons contribute to but do not by themselves ensure deterrence. To have a credible nuclear deterrent requires a nation to have the means, the ability, and the will to employ nuclear weapons. The nation must also have—

- A reliable warning system.
- A modern nuclear force.
- The capability and flexibility to support a spectrum of response options.
- A deployable defensive system for theater protection.

The threat of nuclear escalation is a major concern in any military operation involving the armies of nuclear powers. Controlling escalation is essential to limiting a rational threat's incentive for nuclear response. Escalation control involves a careful selection of options to convey to the enemy that, although the US is capable of escalating operations to a higher level, it has deliberately withheld strikes.

The US views restraint in the use of nuclear weapons as an important way to control the escalation of warfare. Restraint provides leverage for a negotiated termination of military operations. However, the US cannot assume a potential enemy will view restraint in the same way, or that he will not employ weapons of mass destruction. Therefore, the US must be capable of deploying those forces necessary to defeat aggression, provide coercion, and bring the war to a speedy termination on terms favorable to the US and its allies. Commanders and staffs at all levels must continue to be familiar with nuclear-weapons effects, the actions required to minimize such effects, and the risks associated with using nuclear weapons.

THE THREAT

The Cold War era's definitive threats to American security were nuclear surprise attack and the possible invasion of Western Europe. The new threat is worldwide regional instability (including the possible regional use of nuclear weapons) coupled with the proliferation of weapons of mass destruction.

Developing countries as well as regional powers are gaining the ability to manufacture nuclear arsenals. The current threat from developing nations primarily consists of short- and intermediate-range ballistic and cruise missiles and aircraft capable of carrying nuclear weapons and other weapons of mass destruction. Other threats, such as terrorists groups, may also possess nuclear weapons.

A nation that has the capability of using ballistic or cruise missiles and high-speed aircraft to deliver weapons of mass destruction at extended ranges

significantly increases those weapons' effectiveness as instruments of terror. Such capability also enhances the possibility of conflict escalation beyond a hostile region's boundaries.

The use of, or the threat of using, weapons of mass destruction within a campaign or major operation can cause large-scale shifts in objectives, phases, and courses of action (COA). Nuclear weapons make it possible to drastically change the effective ratio of regional forces and equipment and to create conditions favorable to a threat's operations. Consequently, if a potential adversary is not successful conventionally, he might consider using weapons of mass destruction.

The most accepted enemy employment methodology to destroy critical targets is surprise. A potential enemy might try to destroy massed units and all other critical targets using various nuclear-weapons burst options (space bursts, air bursts, surface bursts, below-surface bursts). Such attacks might be single attacks or part of a group of massed nuclear strikes. Therefore, retaliation or escalation would result in the likelihood of nuclear use against friendly forces. Or, retaliation or escalation could be used in response to an enemy's first use of weapons of mass destruction.

One element of the commander's critical information requirements (CCIR) is determining if the theater threat is capable of using weapons of mass destruction. The answer dictates future command actions.

PROLIFERATION, NONPROLIFERATION, AND COUNTERPROLIFERATION

Proliferation is the process by which one nation after another comes into the possession of or attains the right to determine the employment of nuclear weapons, each potentially able to launch a nuclear attack upon another nation. Nonproliferation efforts focus on preventing the spread of missiles and weapons of mass destruction through arms and export controls beyond the scope of corps and EAC interest. Counterproliferation strategy focuses on military measures centering both on how to deter or discourage as well as how to defend and attack against the possible use of such weapons.

The Department of Defense's (DOD) counterproliferation initiative recognizes the goal of preventing proliferation of weapons of mass destruction and their associated delivery systems. It also recognizes that the US must continue to expand its efforts to protect forces, interests, and allies. The initiative has two fundamental goals:

- To strengthen DOD's contribution to governmentwide efforts to prevent, or diplomatically reverse, the acquisition of weapons of mass destruction.
- To protect US interests and forces (as those of its allies) from WMD effects by assuring that US forces have the equipment, doctrine, and intelligence needed to confront, if necessary, any future opponent who possesses weapons of mass destruction.

The Department of Defense marshals its unique technical, military, and intelligence expertise—

- To improve arms control compliance.
- To control exports.
- To inspect and monitor the movement of nuclear materials.
- To interdict shipments for inspection during crises.
- To strengthen the norms and incentives against WMD acquisition.

The Department of Defense's acquisition strategy in the areas of command, control, communications, and intelligence (C^3I), counterforce operations, active defense, and passive defense address the following critical counterproliferation challenges:

- Detecting and destroying WMD capabilities from production through storage to deployment.
- Conducting military operations in a WMD environment.
- Dealing with consequences of WMD use, including medical treatment, clean-up, and recovery.
- Coping with the diffusion of new technologies.

NOTE: This manual concerns the nuclear part of weapons of mass destruction.

Although nuclear weapons are an element of deterrence, potential regional adversaries might or might not understand the deterrence value of the

US' nuclear weapons. If the goals of promoting peace, deterring war, and resolving conflicts fail, deterrence fails. Therefore, fighting and terminating hostilities become paramount. United States doctrine assumes that if the potential foe is capable of using weapons of mass destruction, then US forces must act accordingly.

NUCLEAR FORCES

Nuclear-capable forces (Navy and Air Force) are instruments of national power in regional conflicts. They contribute to theater deterrence or provide a war-fighting option to the NCA.

Because the Army no longer has an organic nuclear capability, the Navy or Air Force will provide nuclear support. The Army can now only nominate nuclear targets, usually at no lower than the corps level. The division normally is limited to NBC protection activities.

The capability of the US to deploy nuclear forces into a theater significantly complicates the enemy's planning process. The alert status of nuclear forces is a function of the world situation at any given time and, thus, enhances their responsiveness.

LEADERSHIP

Battlefield stress in a nuclear environment will be higher than US forces have ever experienced. Only disciplined, well-trained, and physically fit units can function well in such an environment. Commanders who understand this and who provide soldiers with strong, positive leadership; good mental and physical preparation; and clear, comprehensive plans will ensure soldiers are in a better position to survive and win.

Units may have to operate with reduced mutual support and fire support, with degraded electronic communications abilities along extended lines of communications (LOC), and possibly without centralized control or continuous communications. Therefore, to improve command and control (C^2) leaders must work toward three general goals (which take on added importance in nuclear operations):

1. Instill an aggressiveness in their units that will transcend the shock and stress of the nuclear environment.
2. Train junior leaders to think and operate independently.
3. Develop small-unit cohesion.

Commanders and staffs must fully understand the potential of nuclear-weapons use by both an adversary and by a US joint force. They must also have a working knowledge of—

- Nuclear-weapons effects.
- Employment doctrine.
- Survivability measures necessary to preserve combat power.
- Medical requirements as a result of a nuclear explosion.
- The psychological impact of nuclear warfare on soldiers and units.

As commanders plan and fight successive battles involving actual or possible nuclear operations, they must continually assess their soldiers' psychological and physiological stresses. Commanders must emphasize situations in training, exercises, and leadership which will help soldiers accomplish their missions.

TRAINING

On a nuclear battlefield every soldier will confront new and strange circumstances and be under constant danger of attack. Nuclear weapons will quickly cause many casualties as well as intermediate and long-term radiation effects. Soldiers will be exposed to death and destruction of a magnitude far beyond imagination and may have to operate in widely dispersed, isolated, and semiindependent groups. Everyone must understand and practice survival and mitigation techniques. Such techniques will give soldiers direction and confidence in a confusing, frightening situation.

The large and sudden losses that a nuclear attack will cause will shock and confuse inadequately trained or psychologically unprepared troops. Reaction times will be slower, and the ability to respond to leadership and the desire to perform at peak proficiency may be degraded. The violence, stress, and confusion can easily divert attention from battlefield objectives. Extraordinary discipline and leadership are vital to overcoming distractions,

maintaining the mission's focus, and pressing the fight.

Training, the cornerstone of success, technically and psychologically prepares soldiers for the nuclear environment. Successful nuclear operations require expanded combat training that includes—

- Mitigation techniques against nuclear effects.
- Radiation monitoring.
- Decontamination techniques.
- Operations exploiting nuclear-weapons use.
- Recovering and regrouping after an attack.
- Handling mass casualties.
- Having to use degraded resources to accomplish the mission.
- Nominating nuclear targets.

Soldiers will fight as well or as poorly as they have been trained. Clear, concise policies and guidelines provide control and direction. Commanders must emphasize the fact that aggressive maneuver, even by relatively small units, will have a high probability of success in the confused aftermath of a nuclear attack.

NOTE: See FM 25-50 for in-depth discussions of these topics.

SUMMARY

This chapter describes the transition of joint nuclear doctrine to Army-oriented nuclear doctrine. A nuclear environment exists if either adversary in the conflict possesses nuclear capabilities. The levels of war clarify simultaneous activities Army forces conduct in the theater. Each level supports the next higher level of war.

The overall mission of military forces is to deter war—especially nuclear war. If deterrence fails, the US must be capable of deploying the forces necessary to defeat aggression, provide cohesion, and bring war to a speedy termination on terms favorable to the US and its allies.

The threat is worldwide regional instability (including possible use of nuclear weapons) coupled with the proliferation of weapons of mass destruction. Proliferation occurs when nations acquire and have the ability to use nuclear weapons against another nation. Nonproliferation activities attempt to prevent the spread of weapons of mass destruction. Counterproliferation centers on how to deter, defend, and attack against possible use of nuclear weapons.

In the event of either friendly or enemy nuclear-weapons use, commanders must provide soldiers with strong positive leadership, good mental and physical preparedness, and clear comprehensive plans. Positive leadership will ensure soldiers survive and win. Training is the cornerstone for success.

Enemy

Anticipating and planning against the effects of enemy nuclear-weapons use against friendly forces is critical to campaign design. Commanders must ask, "Does the enemy have nuclear capability?" If the answer is no, the question is moot. If the answer is yes, commanders must address issues such as dispersion, type, yield, delivery means, availability of weapons, doctrine, tactics, and the likelihood of use.

Troops

The number and type of troops available could greatly affect the tactical plan. Nuclear weapons can rapidly and decisively enhance combat power. Smaller forces possessing nuclear weapons can accomplish the mission of larger forces not possessing nuclear weapons. The unit's RES determines its fitness for duty. The lower the RES, the healthier the soldiers.

NOTE: See FM 3-3-1.

Terrain and Weather

Terrain and weather can affect nuclear-weapons operations and influence offensive maneuver. For example, tree blowdown in a heavily forested area would obstruct the forward movement of friendly forces.

Normally, tactical fallout will not be significant in a low air burst. However, weather conditions could cause rainout in the area of operations. Therefore, if rain or snow falls through a nuclear cloud, significant tactical fallout may occur. Rain and fog can also lessen the blast wave as it travels through dense air.

Time Available

Offensive actions become harder to conduct when the enemy has had time to organize his defense. The friendly commander can nominate nuclear weapons to effect surprise, prolong confusion, and sustain disorganization. Conversely, the nomination process can erode friendly units' available time because of the necessity of having to relay information and requests up through the chain of command and back down again.

CONDUCTING OFFENSIVE OPERATIONS

The commander plans and coordinates force movement in detail to avoid confusion and delay and to gain surprise. He concentrates his forces quickly, making maximum use of cover and concealment, signal security, and deception while avoiding or masking actions that would alert the enemy to the coming attack. He then conducts the attack rapidly and violently with concentrated firepower to disrupt enemy positions and hit deep in the enemy rear. Nuclear weapons can enhance and support such plans by providing—

- Destructive firepower. Nuclear weapons, even when limited, can help friendly forces cause great destruction of enemy positions with a minimum concentration of forces.
- Surprise. Because delivery of nuclear fires requires little visible unit preparation, surprise can be complete. However, OPSEC within the stockpile-to-target sequence is essential. Forces must avoid a great display of preparation before nuclear strikes to prevent the loss of surprise.
- Shock. Nuclear-weapons use disorganizes, demoralizes, and freezes enemy forces in place. However, these effects will only be temporary; exploitation must be immediate.
- Flexibility. As maneuver forces develop the situation, the commander can nominate nuclear weapons to develop a major operation. He might also substitute nuclear weapons for maneuver forces, allowing a smaller force to succeed in its attack against a stronger force.
- Obstacles. A nuclear weapon can alter terrain to create obstacles such as fallen trees, fires, craters, rubble, and radiation. This nearly instant creation of massive obstacles will allow a smaller force to succeed where a larger force might ordinarily be required. Creation of obstacles slows and canalizes counterattacks and denies terrain to the threat. But, like shock and surprise, obstacles are temporary. Conversely, obstacles can impede forward maneuver if the commander has not considered least-separation distances.

Nuclear weapons can provide the commander with a unique advantage. However, he equally

100-15	*Corps Operations.* This manual contains operational-level doctrine to corps commanders and staffs.
100-16	*Army Operational Support.*
100-17	*Mobilization, Deployment, Redeployment, Demobilization.*

Joint Publications (JP)

1-02	*Department of Defense Dictionary of Military and Associated Terms.*
3-12	*Doctrine for Joint Nuclear Operations.* This publication sets forth doctrine for the combatant commander to use for the conduct of joint nuclear operations. It guides the joint planning and employment of US nuclear forces.
3-12.1	*Doctrine for Joint Nonstrategic Nuclear Weapons Employment.* This publication provides guidance for nuclear-weapons employment. Doctrine and guidance apply to the commander of combatant commands, subordinate unified commands, joint task forces, and subordinate components of these commands.
3-12.2 (SRD)	*Nuclear Weapons Employment and Effects Data* (U). This publication sets forth doctrine and selected TTP for joint operations and training. It is the accepted joint standard for nuclear target analysis, employment procedures, and the source for nuclear effects data.
3-12.3	*Nuclear Weapons Employment and Effects Data.*

Department of Defense Nuclear Agency Effects Manuals (DNA EM)

1 (SRD) Chapter 10 Electromagnetic Pulse.

Chapter 14	Effects of Personnel.
Chapter 15	Damage to Structures.
Chapter 17	Damage to Military Field Equipment.
Chapter 21	Damage to Missiles.

NOTE: DNA is now known as the Defense Special Weapons Agency (DWA).

RELATED PUBLICATIONS

Related publications are sources of additional information. They are not required in order to understand this publication.

Allied Tactical Publications (ATP)

35A	*Land Force Tactical Doctrine.* This publication establishes common NATO doctrine for the use of land force commanders in military operations when NATO forces are placed under their command.

PREDICTION OF URBAN CASUALTIES AND THE MEDICAL LOAD FROM A HIGH-YIELD NUCLEAR BURST

L. Wayne Davis

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The Dikewood Corporation
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Albuquerque, New Mexico 87106

II. CASUALTY CURVES FOR PERSONS IN OR SHIELDED BY STRUCTURES

A. DEVELOPMENT OF "BLAST" MORTALITY CURVES FROM JAPANESE AND TEXAS CITY DATA

A great deal of new information has been gathered concerning the biological effects of the nuclear attacks on Hiroshima and Nagasaki, Japan, during World War II. The data from over 35,000 case histories were collected on magnetic tape, and the results of the analysis were published in DC-FR-1054 (Ref. 3).

The Japanese mortality curves for people in or shielded by structures are plotted as a function of overpressure in Figs. 1 and 2 for Hiroshima and Nagasaki, respectively. These curves are based on a yield for Hiroshima of 12.5 kt burst at a height of 1870 feet (scaled height of 806 feet) and a yield for Nagasaki of 22 kt burst at a height of 1640 feet (scaled height of 585 feet).

The mortality curves from the Texas City disaster of 1947, separated by shielding category, are given as a function of overpressure in Fig. 3. This surface burst* has been estimated to be equivalent to a nuclear yield of 0.67 kt. **(This is the TNT equivalent of 0.88 kt of ammonium nitrate.)**

(Note: at Texas City the S.S. Grandchamp contained 2.3 kt of ammonium nitrate in 100-lb paper bags, but only the 880 tons in No. 4 hatch caught fire and blew up in the initial explosion. The remainder just caused burning debris which set off a fire and later explosion of ammonium nitrate in the Highflyer.)

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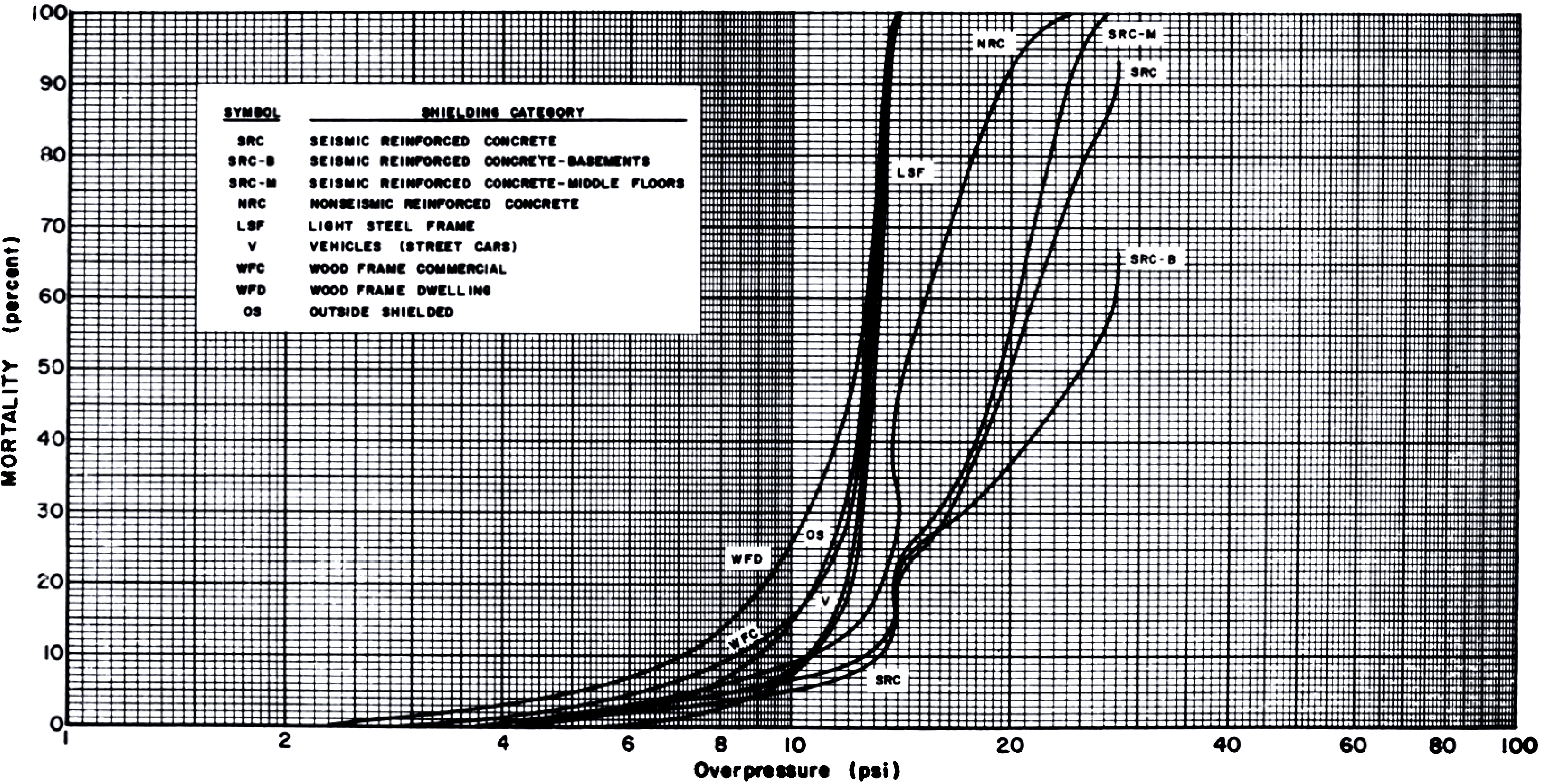
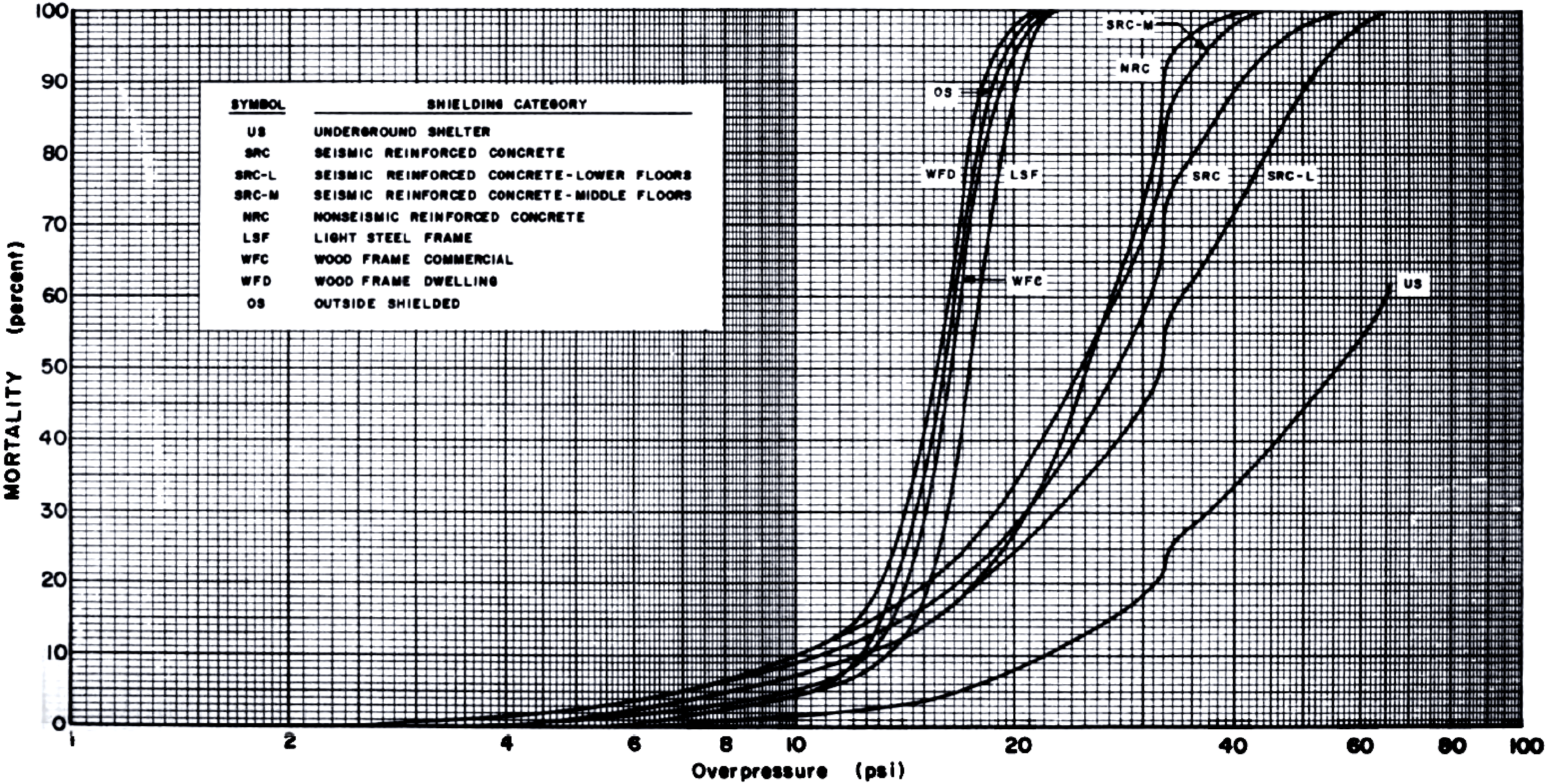
*Ammonium-nitrate fertilizer exploded within the hold of a ship which was tied up at a pier.

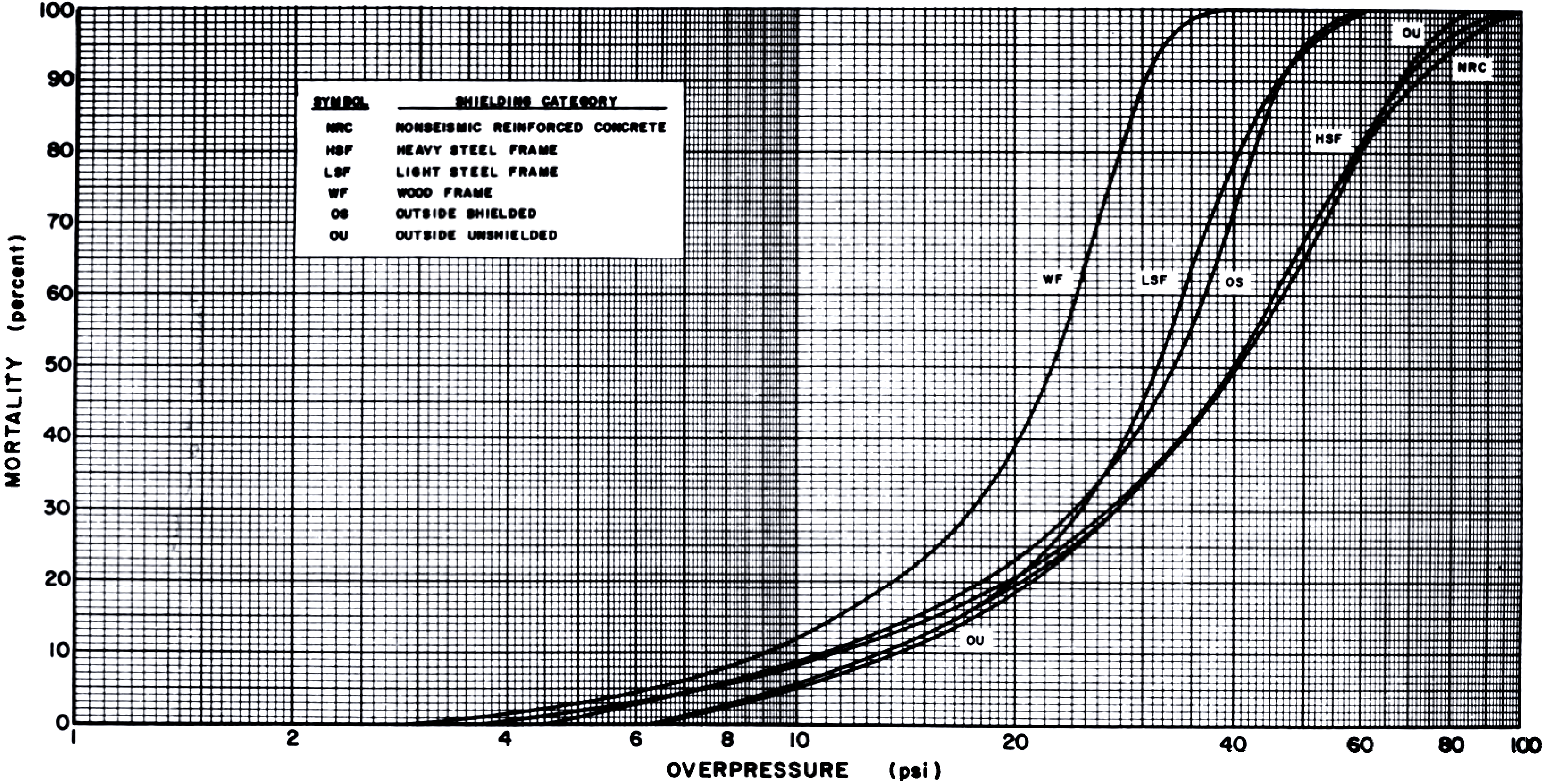
TOTAL MORTALITY CURVES FOR HIROSHIMA



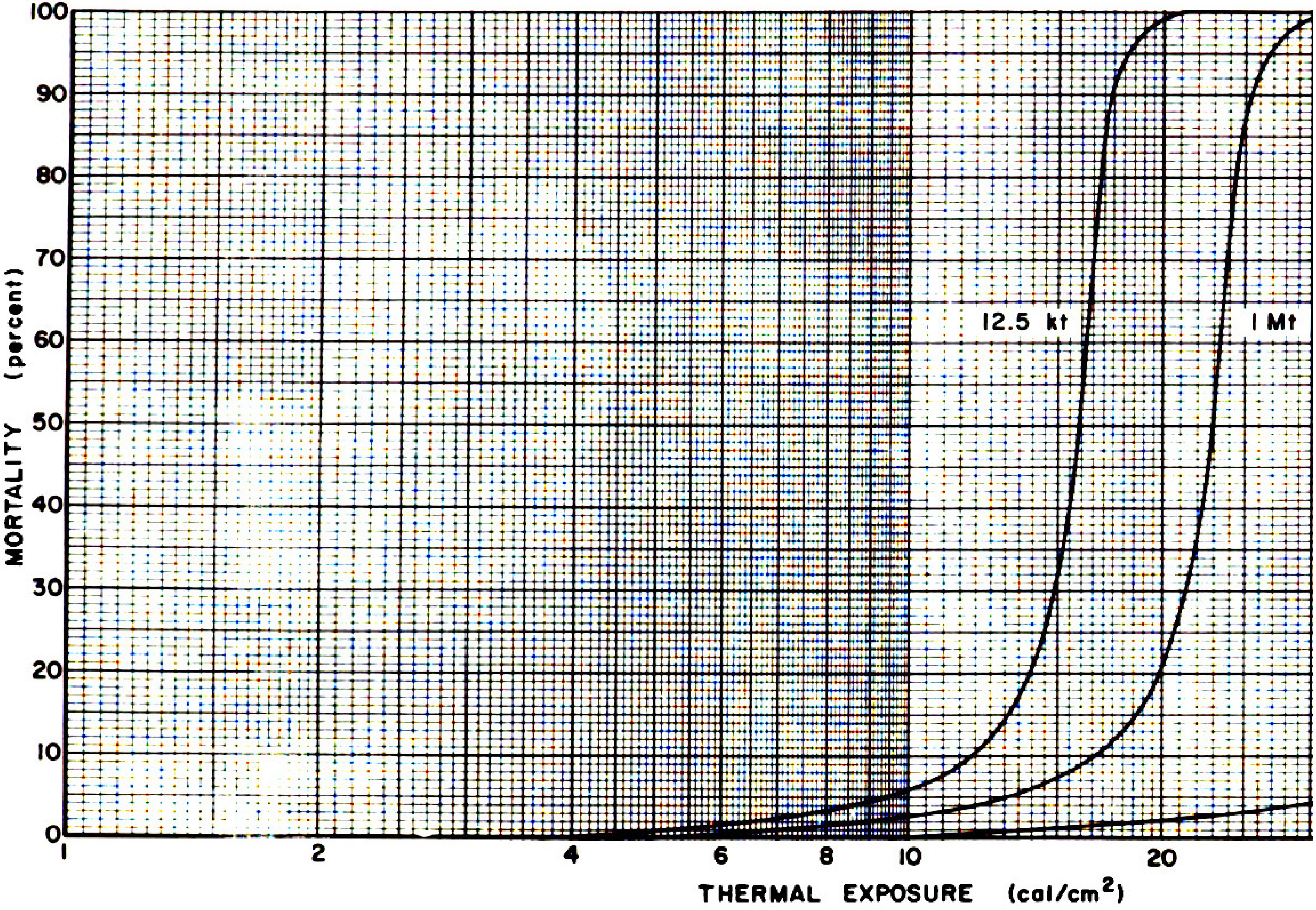
TOTAL MORTALITY CURVES FOR NAGASAKI



TOTAL MORTALITY CURVES FOR TEXAS CITY



FOR OUTSIDE-UNSHIELDED PERSONS



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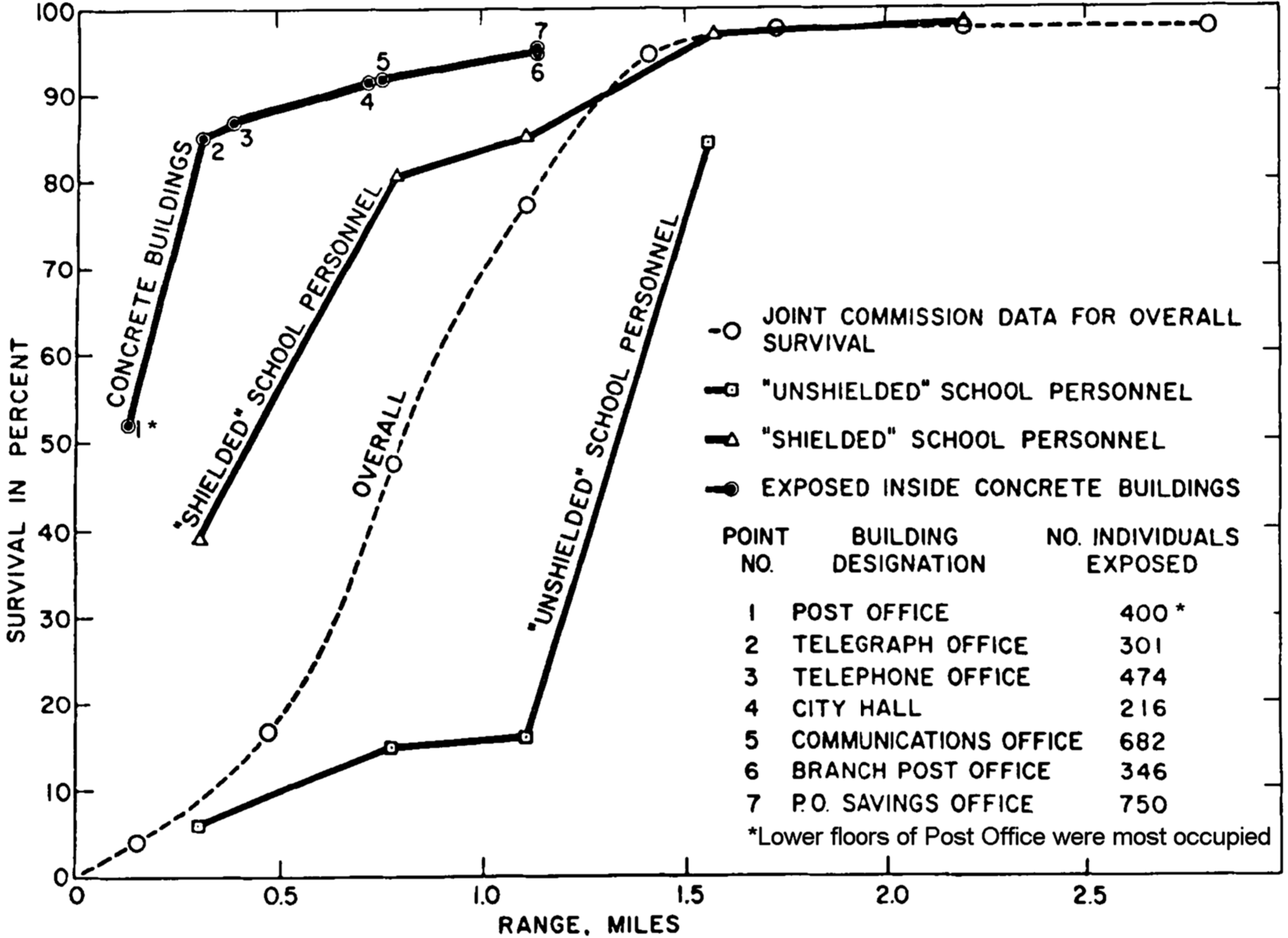

Percentage of survivors as a function of range from Ground Zero (Hiroshima). (Ref. Joint Commission Report, Vol. VI, Document NP-3041.)

The Effects of Atomic Weapons

PREPARED FOR AND IN COOPERATION WITH THE U. S. DEPARTMENT OF DEFENSE AND THE U. S. ATOMIC ENERGY COMMISSION

Under the direction of the

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CHAPTER I [1]

PRINCIPLES OF AN ATOMIC EXPLOSION

A. INTRODUCTION

Characteristics of an Atomic Explosion

1.1 The atomic bomb is a new weapon of great destructive power. It resembles bombs of the more conventional type in so far as its explosive effect is the result of the very rapid liberation of a large quantity of energy in a relatively small space. But it differs from other bombs in three important respects: first, the amount of energy released by an atomic bomb is a thousand or more times as great as that produced by the most powerful TNT bombs; second, the explosion of the bomb is accompanied by highly-penetrating, and deleterious, invisible rays, in addition to intense heat and light; and third, the substances which remain after the explosion are radioactive, emitting radiations capable of producing harmful consequences in living organisms. It is on account of these differences that the effects of the atomic bomb require special consideration.

1.2 A knowledge and understanding of the mechanical and radiation phenomena associated with an atomic explosion are of vital importance. The information may be utilized, on the one hand, by architects and engineers in the design of structures; while on the other hand, those responsible for civil defense, including treatment of the injured, can make preparations to deal with the emergencies that may arise from an atomic explosion.

1.3 During World War II many large cities in England, Germany, and Japan were subjected to terrific attacks by high-explosive and incendiary bombs. Yet, when proper steps had been taken for the protection of the civilian population and for the restoration of services after the bombing, there was little, if any, evidence of panic. It is the purpose of this book to state the facts concerning the atomic bomb, and to make an objective, scientific analysis of these facts. It is hoped that as a result, although it may not be feasible completely to allay fear, it will at least be possible to avoid panic.

---

[1] Material contributed by G. Gamow, S. Glasstone, J. O. Hirschfelder.

8.90 Apart from the effect of the base surge, radioactive contamination will result from the rain produced by the fall-out. There has been some difference of opinion concerning the relative contributions of the base surge and the fall-out to the total radiation dosage. The question is of practical significance, since some protection of personnel from ordinary rainfall, as from the fall-out, is possible in the open. But since the base surge is a cloud which moves laterally, protection from its radiation is not so simple. There is no doubt that at Bikini, the base surge was very significant, and it appears that, in general, both base surge and fall-out will contribute to the radiation dosage, the relative amounts depending on the depth of burst, depth of water, and other conditions.

8.91 From measurements made at the time of the Bikini "Baker" test, it has been possible to draw some general conclusions with regard to the integrated or total radiation dosage received at various distances from surface zero. Actually, about 90 percent of this dosage was attained within 30 minutes of the explosion. The results are represented in the form of radiation dosage contours in Figs. 8.91a,

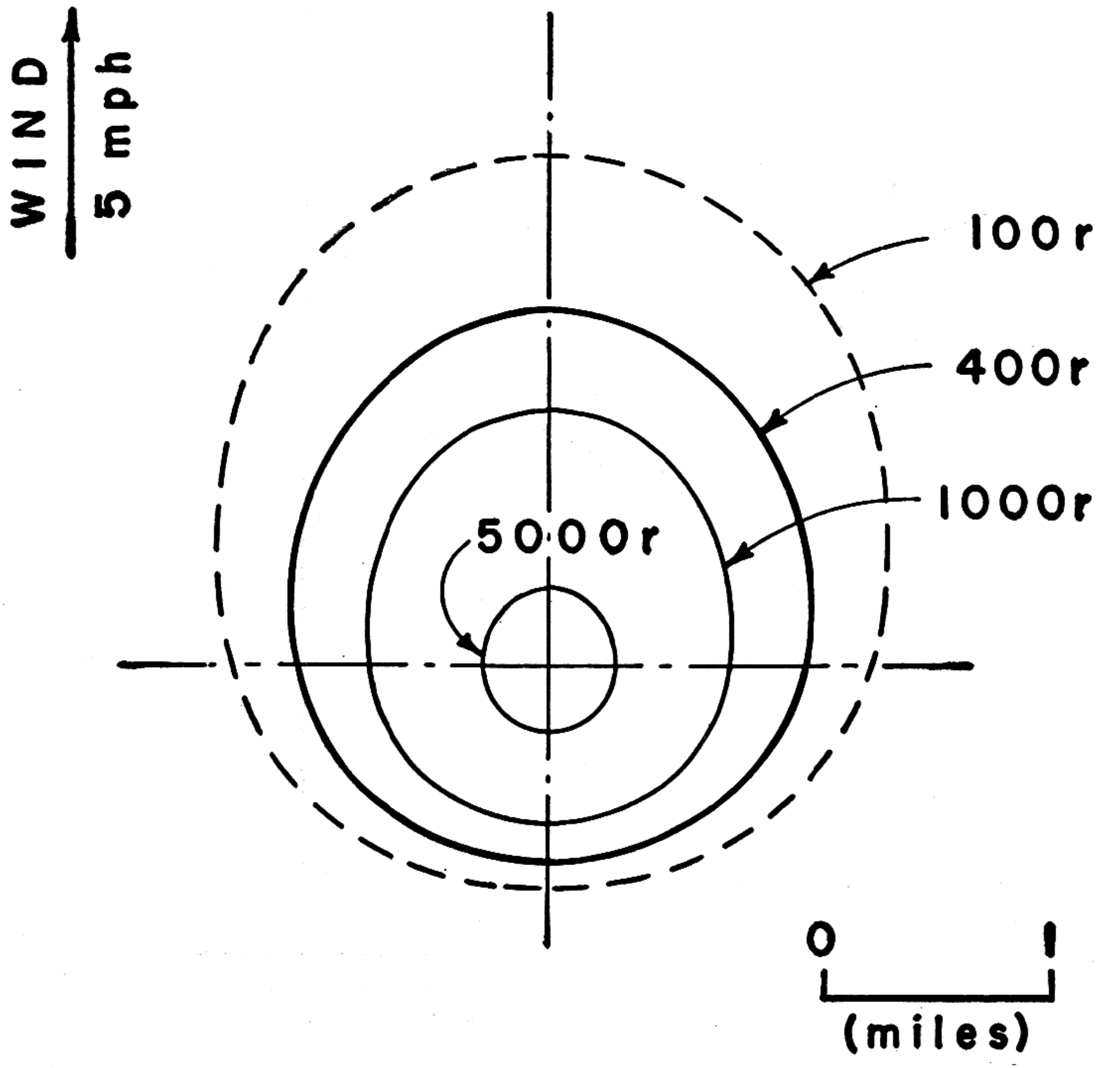

Figure 8.91a. Contours for various integrated radiation dosages due to base surge from underwater burst.

883555°—50——19

b, and c. The dosage due to the base surge mist as it passes over and through an area is shown in Fig. 8.91a. The distortion from symmetry is due to the fact that a wind of about 5 miles per hour was blowing at and near the surface of the lagoon at the time of the detonation. This results, of course, in the radioactive contamination extending much further downwind than in the upwind direction.[19]

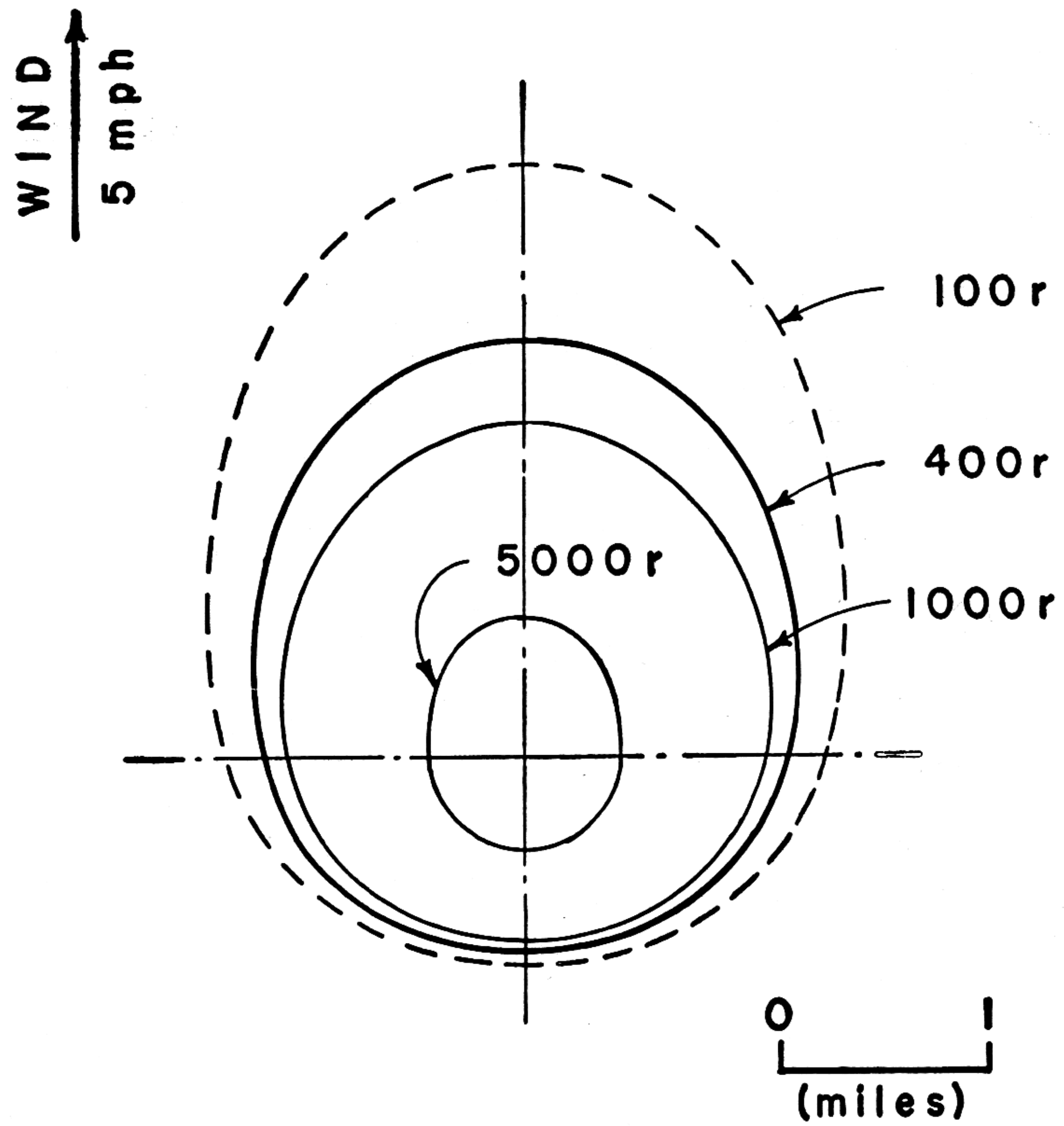

Figure 8.91b. Contours for various integrated radiation dosages due to contamination from underwater burst.

8.92 The integrated dosage contours resulting from contamination due to rain from both the base surge and the fall-out from the atomic cloud, are given in Fig. 8.91b, while Fig. 8.91c indicates the contours for total dosage, i. e., the sum of the base surge and contamination dosages. It is probable that the data in Fig. 8.91b, and hence also in Fig. 8.91c, represent an underestimate, because a proportion of the contaminated water falling as rain ran off the decks of

[19] For the effect of wind on the area, etc., of the base surge, see § 4.79.

the ships and back into the lagoon, so that its activity was not included in the measured dosage.

8.93 It may be mentioned that the radioactive mist of the base surge is most hazardous within the first few minutes of its formation.

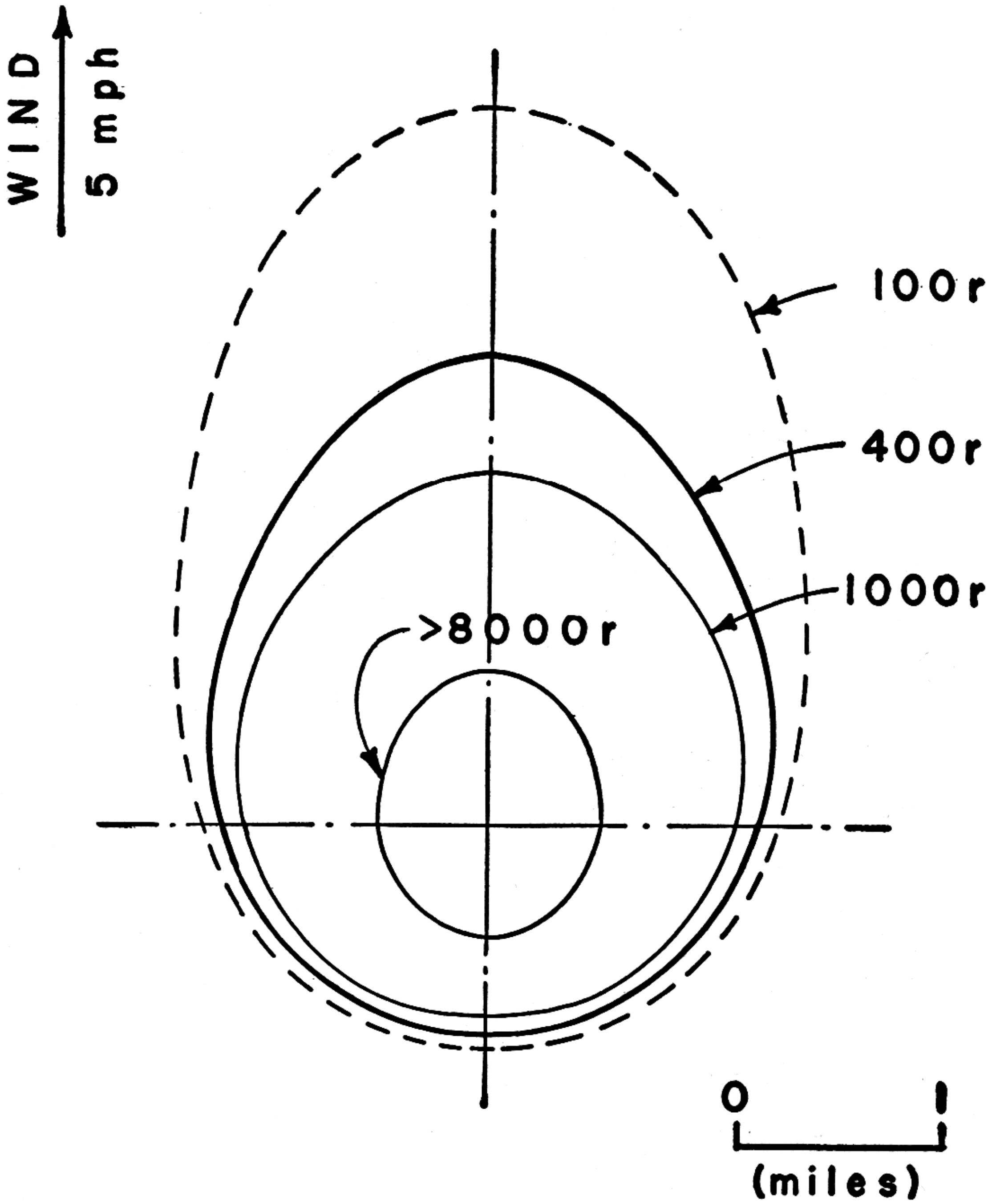

Figure 8.91c. Contours for total dosage due to base surge and contamination from underwater burst.

Its activity decreases rapidly in the course of a short time due to the operation of three factors, namely, dilution by increase of volume as a result of mixing with air, raining out of the active material as the droplets increase in size, and natural radioactive decay. Calculations which probably give a correct order of magnitude, at least, indicate that the dosage rate within the base surge decreases by a factor of about 400 in the interval between 1 and 4 minutes after the

underwater burst. This rapid decrease indicates the advantage of protection from the base surge mist during the 3 or 4 minutes immediately following an atomic explosion. At Bikini, contamination of the interior of the ships, due to the base surge, was minimized by closing down the hatches and stopping the ventilating systems. Attention to this point, especially in the early stages, would obviously prove well worth while.

Radioactivity of Water

8.94 It was recorded earlier that in an underwater burst of an atomic bomb most of the radioactivity of the fission products ultimately appears in the water. Because of the large volume in which these substances are dispersed, the activity in the water is not as high as might be feared, except close to the explosion center and within a short time of the burst. As a result of diffusion of the active material, mixing with water from outside the contaminated area, and natural decay of the radioactivity, the dosage decreases with fair rapidity in a short time. In Table 8.94 are given the area and mean

Table 8.94

DIMENSIONS AND MAXIMUM DOSAGE RATE OF CONTAMINATED WATER IN BIKINI LAGOON

Time after explosion (hours)	*Contaminated area (square miles)*	*Mean diameter (miles)*	*Maximum dosage rate (r per day)*
4	16. 6	4. 6	75
38	18. 4	4. 8	10
62	48. 6	7. 9	5
86	61. 8	8. 9	1
100	70. 6	9. 5	. 6
130	107	11. 7	. 2
200	160	14. 3	. 01

diameter of the contaminated portion of the lagoon after the Bikini "Baker" test, together with maximum observed dosage rates at various times after the burst.

8.95. It is evident that, although a ship would not wish to remain in the contaminated area for any length of time soon after the explosion, passage across the water would not be a great hazard. It is to be understood, of course, that condensers and evaporators would have to be closed down while the ship is in contaminated waters. Further, because of the decrease in activity with time, it seems unlikely that an underwater burst of an atomic bomb would prevent operation of a harbor for any length of time, at least as far as contamination of the water is concerned. However, it should be borne in mind that the

results in Table 8.94, although probably fairly representative, would be affected by the geophysical conditions of the harbor.

8.96 Another factor which contributed to the loss in activity of the water at Bikini was settling of the fission products to the bottom of the lagoon. To judge from samples of bottom material collected 7 and 16 days after the explosion, a considerable proportion of the active material must have been ultimately removed in this manner. The results indicate that the major deposition had occurred within a week and that it covered an area of over 60 square miles. On the assumption that the fission products had penetrated to a depth of 1 foot, it can be estimated that the total mass of the bottom material, in which the radioactivity was distributed, was about 1.4×10^8 tons. Consequently, even though the total initial activity of the fission products was high, about 2×10^6 curies measured a week after the explosion, its wide distribution at the bottom of the lagoon would mean that it did not represent a great hazard to marine life. Observations made several months after the explosion indicated, too, that there was no tendency for the contaminated material to spread.

8.97 It is of interest in this connection to calculate the amount of radiation due to the radioactive isotope of potassium, mass number 40, in sea water. This isotope is present to the extent of 0.012 percent in all forms of potassium, regardless of its source. It emits a beta particle, with a maximum energy of 1.3 Mev, and a gamma photon of 1.5-Mev energy. Because of its long half life, about 1.5×10^9 years, the activity is normally of little significance, although it makes an appreciable contribution to the total background radioactivity of the body (§ 8.49). Since sea water contains 0.4 gram of potassium per liter, the total weight of radiopotassium 40 in the Bikini lagoon is estimated to be 1.4×10^9 grams or 2.1×10^{31} atoms. From the known half life it can be calculated that there will be a total of about 4×10^{14} disintegrations per second, which is equivalent to 10^4 curies of activity due to the potassium 40 alone. In other words, the normal background activity of Bikini lagoon, before the atomic bomb explosion, was at least 10^4 curies. This is not very different from the fission product activity collected at the bottom about 18 months after the detonation.

8.98. There is a possibility that after an underwater burst of an atomic bomb, the radioactivity might be spread over a large area due to the action of marine life. It is well known that land plants absorb and so concentrate mineral elements from the soil and that these are further concentrated in animals feeding on the plants. Similar circumstances arise in water environments; the simple plants, i. e.,

phytoplankton and algae, absorb the nutritive salts from the water, and they are then accumulated in the larger aquatic forms, e. g., fish, which directly or indirectly consume the simple plants.

8.99 In water containing radioactive materials, the latter are concentrated by the fish in the same manner and for the same length of time as are the stable forms of the corresponding elements. If the fish die, the radioactive isotopes are not lost, but they return to the water, as do the stable isotopes, to take part once again in the life cycle. Because of the landlocked nature of the Bikini lagoon, there is evidently little or no outward migration of the larger aquatic organisms so that, as mentioned above, there is no appreciable tendency for the radioactivity to spread. However, due to the behavior of the anadromous migratory fishes, e. g., salmon, shad, etc., which feed in the sea and then migrate upstream to die, or of birds that concentrate the minerals of the sea in guano, there might be some distribution of radioactivity in other cases following an underwater atomic explosion. The extent of such dispersion and its effects would depend greatly on circumstances and appears difficult to estimate.

Radioactive Contamination of Land Areas

8.100 The underwater burst at Bikini took place far enough from shore to prevent any appreciable contamination of land areas. Some radioactive rain fell at large distances from the explosion center (§ 2.36), but the activity was not serious. The possibility must be considered, however, of an underwater atomic explosion so near to the shore that significant amounts of the fall-out and the base surge will reach the adjacent land areas, and possibly affect dock facilities, warehouses, etc. As indicated earlier, because some of the radioactively contaminated water ran off the ships at Bikini, the values in Figs. 8.91b and 8.91c may represent an underestimate if applied to the shore. However, there may be compensating factors in the deposition of active material on the roofs or protruding portions of buildings, and also because of the shielding effects of various structures.

8.101 A rough attempt to assess the contamination, in terms of radiation dosage rates, of adjacent land areas from the underwater burst of a nominal atomic bomb, at 1 hour after the explosion is made in Fig. 8.101. The results are based on the assumption that the activity is due to fission products with a mean gamma-ray energy of 0.7 Mev (§ 8.11). Four contour lines are shown, representing radiation dosage rates of 400, 50, 10, and almost zero roentgens per hour, respectively. In the region outside the last contour line, the danger

12.59 If a person is in the open when the sudden illumination is apparent, then the best plan is instantaneously to drop to the ground, while curling up so as to shade the bare arms and hands, neck, and face with the clothed body. Although this will not protect against gamma rays, it may help in reducing flash burns (§ 6.53). This is important since disabling burns can be suffered well beyond the lethal range for gamma rays (Fig. 12.13). The curled-up position should be held for at least 10 seconds; the immediate danger is then over, and it is permissible to stand up and look around to see what action appears advisable.

12.60 If in the street, and some sort of protection, such as a doorway, a corner or a tree is within a step or two, then shelter may be taken there with the back to the light, and in a crouched position to provide maximum protection, as described above. No attempt should be made to reach a shelter if it is several steps off; the best plan then is to crouch on the ground, as if completely in the open. After 10 seconds, at least, a standing position may be resumed, but it is strongly advisable to press the body tightly against the side of a building to avoid breaking glass or falling missiles, as far as possible.

12.61 A person who is inside a building or home when a sudden atomic bomb attack occurs should drop to the floor, with the back to the window, or crawl behind or beneath a table, desk, counter, etc.; this will also provide a shield against splintered glass due to the blast wave. The latter may reach the building some time after the danger from radiation has passed, and so windows should be avoided for about a minute, since the shock wave continues for some time after the explosion. The safest places inside a building are the interior partitions, and it is desirable to keep as close to these as possible.

D. PROTECTION FROM RESIDUAL RADIATIONS

Introduction

12.62 As stated earlier, protection of large numbers of people from the effects of the residual nuclear radiations, that might follow the explosion of an atomic bomb, represents an entirely new problem concerning which there has been no previous experience. After the attacks on Japan the fission products were so widely dispersed as not to be an appreciable danger; at least, there is no evidence that such a hazard existed. In special circumstances, however, for example, an underwater burst close to the shore or an underground or surface burst, or in the event of the use of radiological warfare weapons, pre-

cautions would have to be taken against the residual radiations. In the present section an outline will be given of the general lines of procedure that might be followed for radiological defense; in view of the lack of experience, these may be regarded as tentative and subject to improvement.

12.63 Since the possibility of combating radioactive contamination is bound up with the extent of the associated physical damage, it is desirable to make a rough classification of the possible combinations that might arise. Three general types may be distinguished:

(a) *Heavy Physical Damage and Heavy Contamination.*—Such a condition might be due to a combination of an air-burst atomic bomb followed, or accompanied, by the use of a radiological weapon. In view of the wasteful nature of such action, it may be regarded as not too probable, although it cannot be ignored. An underwater burst in a harbor of a large city, close to the shore, might cause both heavy damage and contamination over a limited area. In this event, radiological safety measures might be delayed by the necessity of clearing away debris, establishing communications, etc.

(b) *Heavy Physical Damage and Light Contamination.*—This would arise from an atomic explosion of the type experienced at Hiroshima and Nagasaki. The problem of protection against radioactivity would not be serious in this case. It would be necessary for monitoring teams to follow the radioactive cloud downwind in case there were a marked fall-out in any particular area. It is of almost equal importance to know definitely that there is no hazard.

(c) *Moderate or Little Physical Damage and Moderate to Heavy Contamination.*—Such circumstances could arise from a radiological warfare attack, from dry or wet fall-out, from base surge on a ship or on shore at some distance from an underwater explosion, or from an ineffective ("fizzle") explosion of an atomic bomb. The radioactive protection would be of the greatest significance, and to meet these conditions the radiological defense system must be especially prepared.

Stages of Disaster

12.64 In considering the practical problems of a radiological hazard it may be supposed that there will be three stages, the duration and

severity of which will depend on circumstances described above. These are as follows:

(*a*) *Complete Disorganization.*—In the event of heavy and widespread physical damage, it may be presumed that roads will be blocked for some distance from the explosion, and that all normal communication systems will be out of commission. Emergency transportation and communication, except perhaps for self-contained radio equipment, will not be immediately in effect.

(*b*) *Emergency Control Stage.*—This phase will begin as soon as margin roads have been cleared, and transportation and communication has been reestablished, at least on an emergency scale, so that information can be transmitted to a control room. In the case of moderate physical disaster (§ 12.63 (*c*)), the emergency control phase would start immediately, and might last a week or more.

(*c*) *Recovery Stage.*—The final phase would be reached when most people were out of immediate danger of injury, and there is time to start more thorough decontamination operations where necessary (Chapter X).

12.65 In the emergency control phase, an important factor in the operation of radiological defense is the rapid gathering of data regarding contamination. The radiations which may be encountered are gamma rays and beta particles from fission products, neutron-induced activity or other radioactive material, and alpha particles from plutonium or uranium. Of these, the gamma radiation can be measured most readily; this is perhaps the greatest immediate hazard because of its considerable penetrating power. Beta particles as such are not a serious menace unless the source enters the system or remains on the skin for some time.

12.66 Monitoring of suspected contaminated areas for gamma radiation should be carried out at the earliest possible moment after an atomic explosion in which such contamination is likely to have been produced. Initially, this might even be done by means of low-flying aircraft; from the gamma radiation dosage measured at a known height above the ground it will be possible to obtain an approximate indication of the area and intensity of contamination (see Fig. 8.35). However, ground monitoring for gamma radiation, with portable instruments, will be necessary at the first opportunity. The monitoring for beta radiation will, in general, be an auxiliary measurement, made in the later stages after the immediate emergency has passed.

The Effects of

Nuclear Weapons

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Editor

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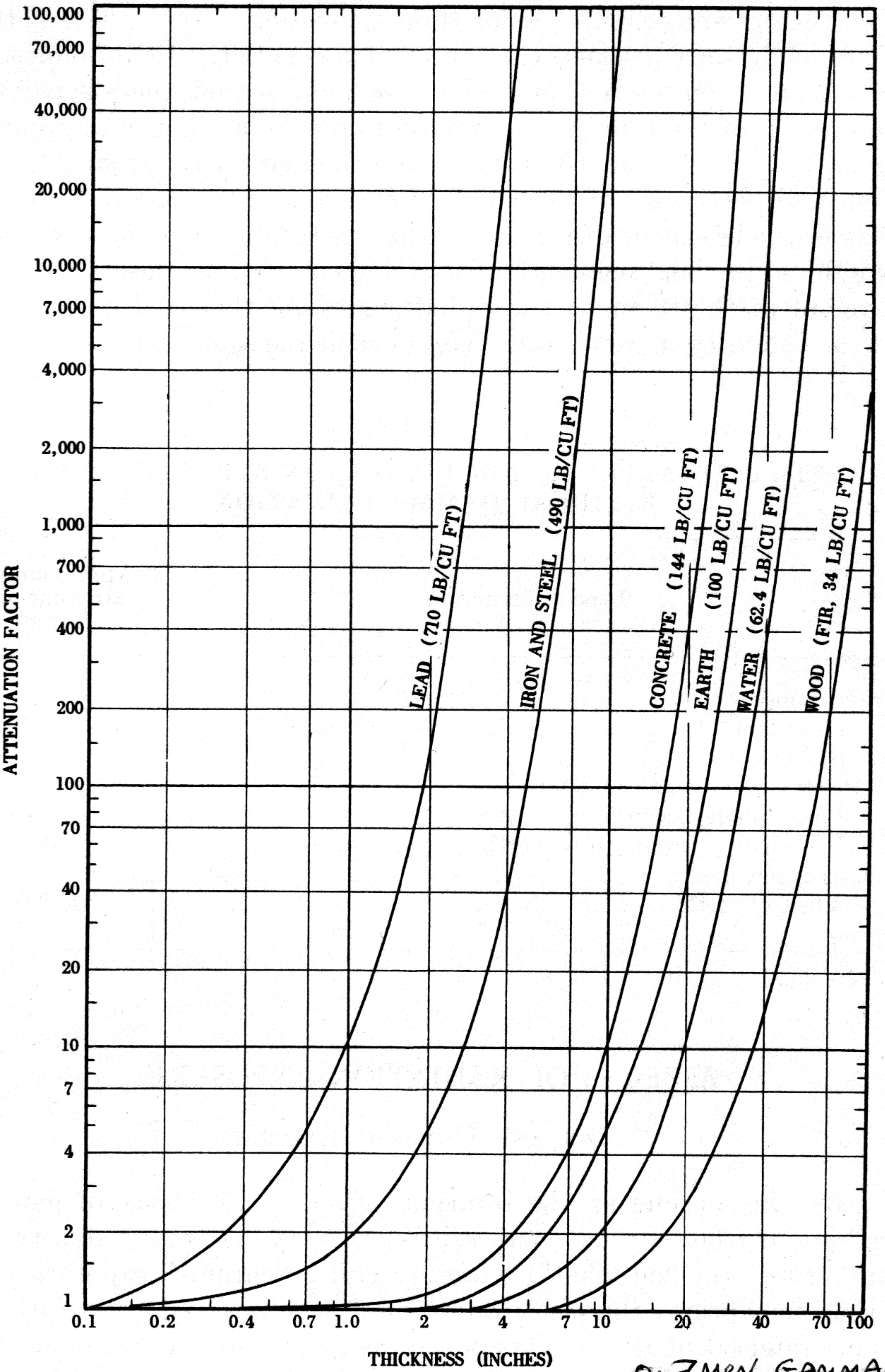


0.7 MeV GAMMAS

Figure 9.36. Attenuation of fission product radiation. (FALLOUT)

9.42 An estimate of the total radiation dose, due to purely natural sources, received per annum by human beings, over the whole body, is given in Table 9.42. It is assumed that the underlying rock is granite, and data are given for sea level and an elevation of 5,000 feet. In some locations the background radiation dose from soil and rocks is less than from granite, but it appears that, in most parts of the United States, the natural radiation exposure dose is about 0.14 to 0.16 roentgen per year.

TABLE 9.42

ESTIMATED DOSE PER ANNUM FROM NATURAL BACKGROUND RADIATION

Radiation source	Roentgens per year	
	Sea level	5,000 feet altitude
Potassium in body	0. 020	0. 020
Thorium, uranium, and radium in granite	0. 055	0. 055
Potassium in granite	0. 035	0. 035
Cosmic rays	0. 035	0. 050
Total	0. 145	0. 16

9.43 It follows, therefore, that during the average lifetime every human being receives a total of 10 to 12 roentgens of nuclear radiation over the whole body from natural sources. In addition, there may be localized exposures associated with dental and chest X-rays, and similar treatments, and even from the luminous dials of wrist watches and instruments. The exposure to radiation from natural sources has undoubtedly continued during the whole period of man's existence.

TABLE 11.72

SUMMARY OF CLINICAL SYMPTOMS OF RADIATION SICKNESS

Time after exposure	Survival improbable (700 r or more)	Survival possible (550 r to 300 r)	Survival probable (250 r to 100 r)
	Nausea, vomiting, and diarrhea in first few hours.	Nausea, vomiting, and diarrhea in first few hours.	Possibly nausea, vomiting, and diarrhea on first day.
1st week	No definite symptoms in some cases (latent period).		
	Diarrhea Hemorrhage Purpura Inflammation of mouth and throat. Fever	No definite symptoms (latent period).	No definite symptoms (latent period).
2nd week	Rapid emaciation Death (Mortality probably 100 percent).	Epilation Loss of appetite and general malaise. Fever	
3rd week		Hemorrhage Purpura Petechiae Nosebleeds Pallor Inflammation of mouth and throat. Diarrhea Emaciation	Epilation Loss of appetite and malaise Sore throat Hemorrhage Purpura Petechiae Pallor Diarrhea Moderate emaciation.
4th week			
		Death in most serious cases. (Mortality 50 percent for 450 roentgens.)	Recovery likely in about 3 months unless complicated by poor previous health or superimposed injuries or infections.

12.86 In a city, decontamination could be carried out by hosing the roofs of buildings and the streets with strong streams of water. The radioactive material would thus be transferred to the storm sewers, where it would represent only a minor hazard. As an alternative to hosing, the dose rate inside a building could also be reduced by covering the ground surrounding the building with uncontaminated earth or by removing the top layer of the ground to a distance with a bulldozer.

12.87 It is important to note, in connection with removal of contaminated earth, for the purpose just described or to provide a means of transit, that the gamma rays from fission products can travel considerable distances through air. For example, at 3 feet above the ground, roughly 50 percent of the dose rate received in the center of a large, flat, uniformly contaminated area comes from distances greater than 25 feet away, and about 25 percent from distances more than 50 feet away. Thus, complete removal of the contaminated surface from a circle 50 feet in radius would reduce the dose rate in the center to about one-fourth of its original value. However, if the contaminated earth were not completely removed, but just pushed to the outside of the circle, the dose rate would be considerably larger than one-fourth the initial value.

12.88 It is apparent, therefore, that if transit facilities are to be provided across open country which is contaminated over a large area, bulldozing the top few inches of contaminated soil to the sides will be satisfactory only if a wide strip is cleared. Thus, if the strip is 250 feet in width, the radiation dose rate in the middle will be reduced to one-tenth of the value before clearing. A similar result may be achieved by scraping off the top layer of soil and burying it under fresh soil. Something like a foot of earth would be required to decrease the dose rate by a factor of ten.

12.89 Badly contaminated clothing, as well as rugs, curtains, and upholstered furniture, would have to be discarded and buried or stored in an isolated location. When the radioactivity has decayed to a sufficient extent, or if the initial contamination is not too serious, laundering may be effective in reducing the activity of clothing and fabrics, to permit their recovery. Thorough vacuum cleaning of furniture might be adequate in some cases, but an instrument check would be necessary before further use.

Protection of Operating Crews

12.90 All personnel entering a contaminated area, to perform survey monitoring, decontamination, or other emergency operations, should adapt their clothing to prevent the entry of dust. The main purpose of this precaution is to minimize the possibility of "beta burns" as a result of direct contact of the fallout with the skin (see § 11.94). It should be remembered, of course, that clothing offers virtually no protection against gamma radiation, and so this hazard will still exist to an undiminished extent.

12.91 For dry operations, heavy pants and shoes are recommended, as well as cotton or canvas work gloves and a tight-fitting cap. In dusty areas it is advisable that the bottoms of the pants and the ends of the sleeves (over the gloves) be tied to prevent the entry of contaminated material. A scarf around the neck would also help in this connection. After a nuclear attack, the dust may arise from rubble, disturbance of the ground, etc., and may not necessarily be radioactive. Precautions to reduce inhalation of the dust in large amounts would be desirable, in any event. Consequently, in operations in which considerable quantities of dust may be encountered, goggles and a filter mask are advisable.

12.92 For wet decontamination operations, water-repellent clothing, rubber boots, and rubber gloves will be required (Fig. 12.92). They can be cleaned with a stream of water and used several times, provided there are no breaks or tears.

12.93 In addition to taking steps to prevent radioactive material from reaching the skin, workers will need protection from excessive exposure to radiation. For this purpose, each operator should carry a self-indicating meter, sometimes called an "organizational dosimeter," to record his total radiation exposure. Various types of dosimeters have been devised, and simple and reliable instruments, that can be produced cheaply and in large numbers, are available.[6]

12.94 Survey meters for the determination of radiation intensities (dose rates) will be required in order to detect regions of high activity and for estimating permissible times of stay in a contaminated area. As a general rule, instruments which measure the dose rate of gamma radiation will be satisfactory. In addition, special instruments sensitive to beta radiations are advantageous for such purposes as detecting beta-particle emitters on the body.

[6] For a description of dosimeters and other radiation instruments developed by the Federal Civil Defense Administration, see "Radiological Instruments for Civil Defense," TB-11-20.

Food and Water

12.97 Foods that are properly covered or wrapped or are stored in closed containers should suffer little or no contamination. This will be true for canned and bottled foods as well as for any articles in impervious, dust-proof wrappings. If the contamination is only on the outside, all that would be necessary for recovery purposes would be the careful removal, e. g., by washing, of any fallout particles that might have settled on the exterior of the container. Even vegetables could be satisfactorily decontaminated by washing. If this were followed by removal of the outer layers, by peeling, the food should be perfectly safe for human consumption.

12.99 Most sources of public water supplies are located at a considerable distance from urban centers that might be targets of a nuclear attack. Nevertheless, appreciable contamination might result if the watershed were in the range of heavy fallout from a surface burst. Other possibilities are fallout particles dropping into a river or reservoir or the explosion of a nuclear bomb near a reservoir. In most cases it is to be expected that, as a result of the operation of several factors, e. g., dilution by flow, natural decay, and removal ("adsorption") by soil, the water will be fit for consumption, on an emergency basis, at least, except perhaps for a limited time immediately following the nuclear explosion. In any event, where the water from a reservoir is subjected to regular treatment, including coagu-

lation, sedimentation, and filtration, it is probable that much of the radioactive material would be removed.

12.100 Because soil has the ability to take up and retain certain elements by the process of "adsorption," underground sources of water will generally be free from contamination.

12.101 In some cities, water is taken directly from a river and merely chlorinated before being supplied for domestic purposes. The water may be unfit for consumption for several days, but, as a result of dilution and natural decay, the degree of contamination will decrease with time.

Table 12.101

ACCEPTABLE EMERGENCY BETA (OR GAMMA) ACTIVITIES IN DRINKING WATER

	Activity	
Consumption period (days)	*Microcuries per cubic centimeter*	*Disintegrations per second per cubic centimeter*
10	9×10^{-2}	3×10^{3}
30	3×10^{-2}	1×10^{3}

Figure 12.40a. Earth-moving equipment subjected to nuclear blast in open terrain (30 psi overpressure). **Teapot-MET, 1955**

Figure 12.40b. Earth-moving equipment subjected to nuclear blast in open terrain (30 psi overpressure). **Teapot-MET, 1955**

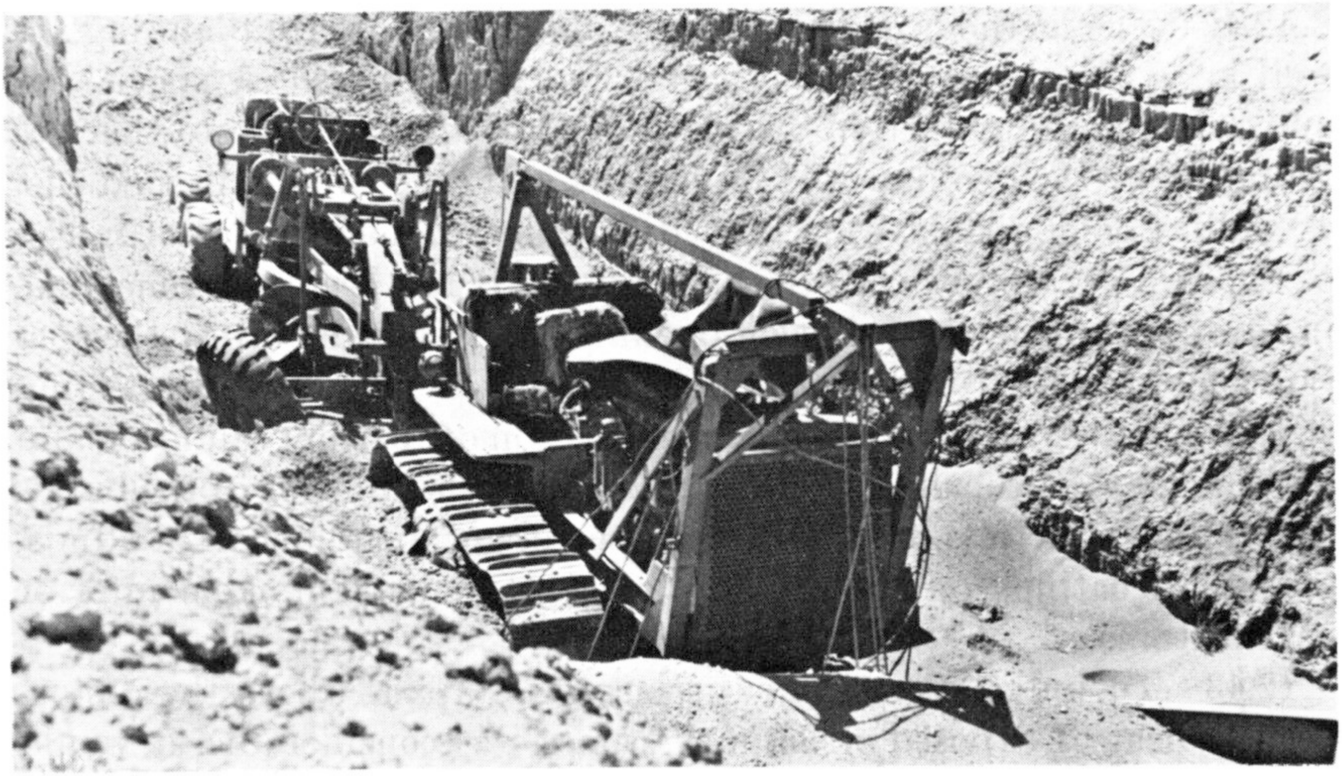


Figure 12.40c. Earth-moving equipment protected in deep trench at right angles to blast wave motion (30 psi overpressure).

Teapot-MET, 1955

12.40 The destruction caused by a nuclear explosion to two pieces of earth-moving equipment, which are largely drag-sensitive, is shown in Figs. 12.40a and b. Two similar pieces of equipment located in a deep trench, at the same distance from the explosion, are seen in Fig. 12.40c to have been essentially unharmed. It is important to mention that the main direction of the trench was at right angles to the motion of the blast wave. If the wave had been traveling in the same direction as the trench, the equipment would probably have been severely damaged. Consequently, in order to provide protection from drag forces, the orientation of the trench or earth revetment, with respect to the expected direction of the explosion, is of great importance.

Fire Protection

12.41 It was noted in Chapter VII that fires following a nuclear explosion may be started by thermal radiation and by secondary effects, such as overturning stoves and furnaces, rupture of gas pipes, and electrical short circuits. Fire-resistive construction and avoidance of fabrics and other light materials of inflammable character are essential in reducing fire damage. As shown by the tests described in § 7.82, a well-maintained house, with a yard free from inflammable rubbish, was less easily ignited by thermal radiation than a house that has not had adequate care.

12.60 In the event of a surprise attack, when there is no opportunity to take shelter, immediate action could mean the difference between life and death. The first indication of an unexpected nuclear explosion would be a sudden increase of the general illumination. It would then be imperative to avoid the instinctive tendency to look at the source of light, but rather to do everything possible to cover all exposed parts of the body. A person inside a building should immediately fall prone and crawl behind or beneath a table or desk. This will provide a partial shield against splintered glass and other flying missiles. No attempt should be made to get up until the blast wave has passed, as indicated possibly by the breaking of glass, cracking of plaster, and other signs of destruction. The sound of the explosion also signifies the arrival of the blast wave.

12.61 A person caught in the open by the sudden brightness due to a nuclear explosion, should drop to the ground while curling up to shade the bare arms, hands, neck, and face with the clothed body. Although this action may have little effect against gamma rays and neutrons, it might possibly help in reducing flash burns due to thermal radiation. The degree of protection provided will vary with the energy yield of the explosion. As stated in § 7.53, it is only with high-yield weapons that evasive action against thermal radiation is likely to be feasible. Nevertheless, there is nothing to be lost, and perhaps much to be gained, by taking such action. The curled-up position should be held until the blast wave has passed.

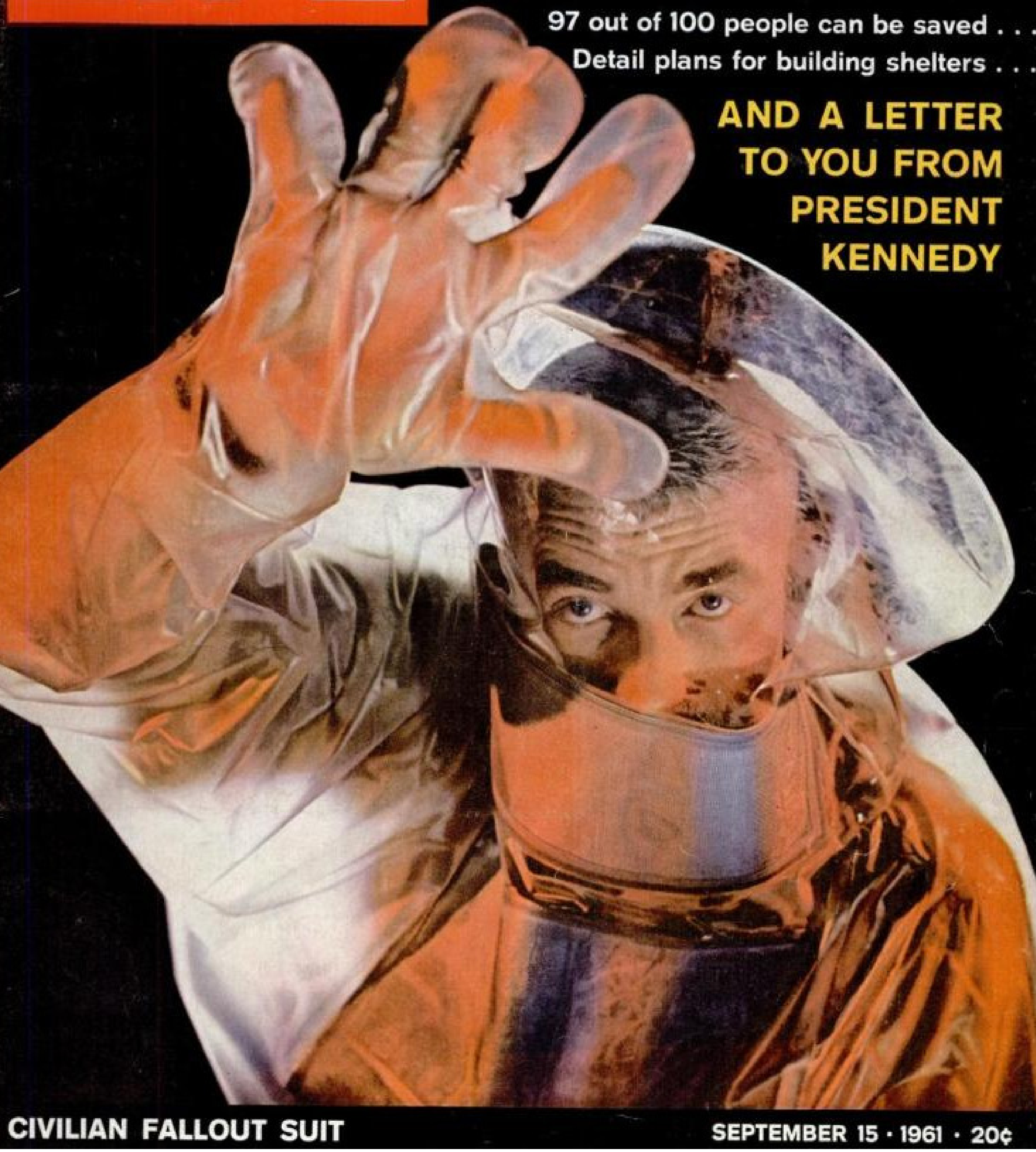
12.62 If shelter of some kind, no matter how minor, e. g., in a doorway, behind a tree, or in a ditch, or trench can be reached within a second, it might be possible to avoid a significant part of the initial nuclear radiation, as well as the thermal radiation. But shielding from nuclear radiation requires a considerable thickness of material and this may not be available in the open. By dropping to the ground, some advantage may be secured from the shielding provided by the terrain and surrounding objects. However, since the nuclear radiation continues to reach the earth from the atomic cloud as it rises, the protection will be only partial. Further, as a result of scattering, the radiations will come from all directions.

LIFE

HOW YOU CAN SURVIVE FALLOUT

97 out of 100 people can be saved . . .
Detail plans for building shelters . . .

AND A LETTER TO YOU FROM PRESIDENT KENNEDY



CIVILIAN FALLOUT SUIT

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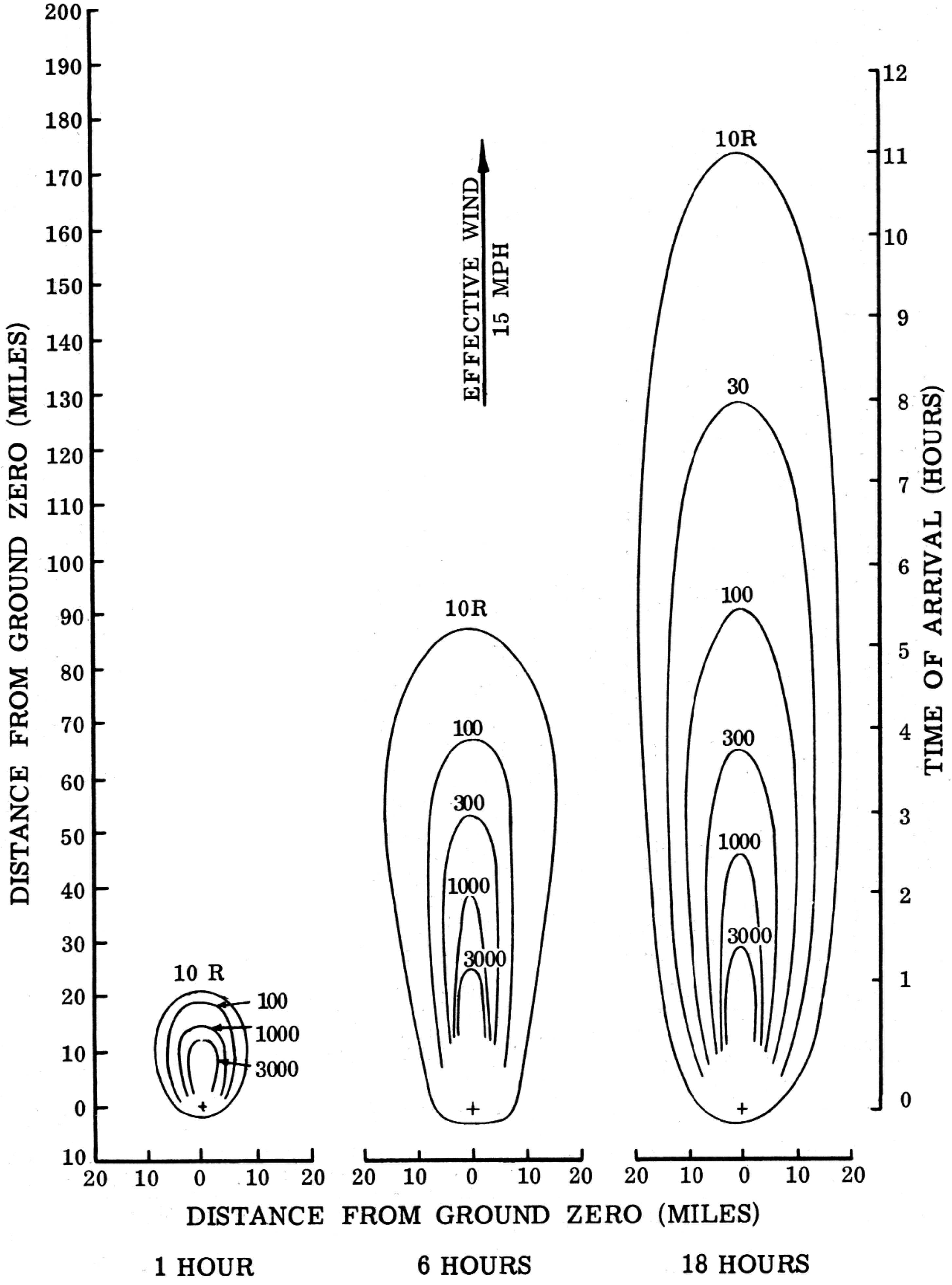

Figure 9.67b. Total-dose contours from early fallout at 1, 6, and 18 hours after surface burst with 1-megaton fission yield (15 mph effective wind speed).

11.149 Valuable information concerning the development and healing of beta burns has been obtained from observations of the Marshall Islanders who were exposed to fallout in March 1954. Within about 5 hours of the burst, radioactive material commenced to fall on some of the islands. Although the fallout was observed as a white powder, consisting largely of particles of lime (calcium oxide) resulting from the decomposition of coral (calcium carbonate) by heat, the island inhabitants did not realize its significance. Because the weather was hot and damp, the Marshallese remained outdoors; their bodies were moist and they wore relatively little clothing. As a result, appreciable amounts of fission products fell upon the hair and skin and remained there for a considerable time. Moreover, since the islanders, as a rule, did not wear shoes, their bare feet were continually subjected to contamination from fallout on the ground.

11.150 During the first 24 to 48 hours, a number of individuals in the more highly contaminated groups experienced itching and a burning sensation of the skin. These symptoms were less marked among those who were less contaminated with early fallout. Within a day or two all skin symptoms subsided and disappeared, but after the lapse of about 2 to 3 weeks, epilation and skin lesions were apparent on the areas of the body which had been contaminated by fallout particles. There was apparently no erythema, either in the early stages (primary) or later (secondary), as might have been expected, but this may have been obscured by the natural coloration of the skin.

11.151 The first evidence of skin damage was increased pigmentation, in the form of dark colored patches and raised areas (macules, papules, and raised plaques). These lesions developed on the exposed parts of the body not protected by clothing, and occurred usually in the following order: scalp (with epilation), neck, shoulders, depressions in the forearm, feet, limbs, and trunk. Epilation and lesions of the scalp, neck, and foot were most frequently observed (Figs. 11.151 a and b).

11.152 In addition, a bluish-brown pigmentation of the fingernails was very common among the Marshallese and also among American Negroes. The phenomenon appears to be a radiation response peculiar to the dark-skinned races, since it was not apparent in any of the white Americans who were exposed at the same time. The nail pigmentation occurred in a number of individuals who did not have skin lesions. It is probable that this was caused by gamma rays, rather than by beta particles, as the same effect has been observed in dark-skinned patients undergoing X-ray treatment in clinical practice.

11.153 Most of the lesions were superficial without blistering. Microscopic examination at 3 to 6 weeks showed that the damage

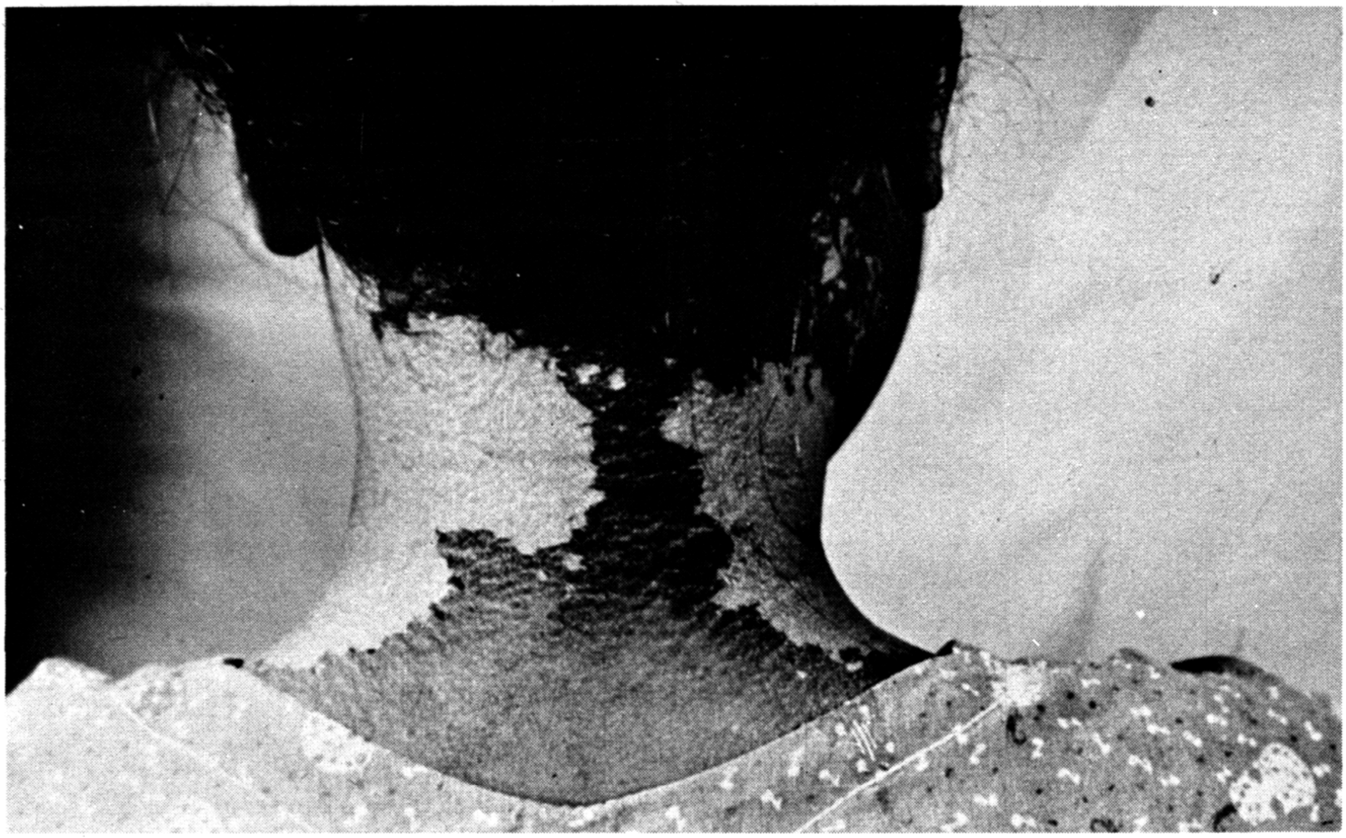

Figure 11.151a. Beta burn on neck 1 month after exposure.

was most marked in the outer layers of the skin (epidermis), whereas damage to the deeper tissue was much less severe. This is consistent with the short range of beta particles in animal tissue. After formation of dry scab, the lesions healed rapidly leaving a central depigmented area, surrounded by an irregular zone of increased pigmentation. Normal pigmentation gradually spread outward in the course of a few weeks.

11.154 Individuals who had been more highly contaminated developed deeper lesions, usually on the feet or neck, accompanied by mild burning, itching, and pain. These lesions were wet, weeping, and ulcerated, becoming covered by a hard, dry scab; however, the majority healed readily with the regular treatment generally employed for other skin lesions not connected with radiation. Abnormal pigmentation effects persisted for some time, and in several cases about a year elapsed before the normal (darkish) skin coloration was restored (Figs. 11.154 a and b).

11.155 Regrowth of hair, of the usual color (in contrast to the skin pigmentation) and texture, began about 9 weeks after contamination and was complete in 6 months. By the same time, nail discoloration had grown out in all but a few individuals. Seven years later, there were only 10 cases which continued to show any effects of beta burns, and there was no evidence of malignant changes.

CHAPTER XII

PRINCIPLES OF PROTECTION

BASIS FOR PROTECTIVE ACTION

Introduction

12.01 In the preceding chapters the phenomena and the destructive effects of nuclear explosions have been described in terms that are reasonably exact. In addition, the best available assessment of these effects on man have been presented. But in planning protection from the consequences of a nuclear explosion, so many uncertainties are encountered that precise analysis of a particular situation is impractical. For example, it is impossible to know in advance where or when a weapon will be detonated and what will be the explosive energy or the kind of burst. Nevertheless, there are some basic principles which, if properly understood and applied, could provide a measure of protection to a large proportion of the population in the event of a nuclear attack.

12.02 The most fruitful application of the principles of protection requires considerable preplanning on the part of individuals; however, some protection may be possible even in certain emergency situations if the principles are understood beforehand. It is the purpose of this chapter to present the quantitative aspects of weapons effects in a simplified form and to use them to explain the principles of protection. The information provided should be helpful in indicating the nature of the protection required and what steps must be taken in advance to achieve such protection. However, details of specific measures are not included since they are described in other publications.[1]

12.03 In the following sections the various effects of a nuclear explosion will be reviewed, with special reference to their ranges, and the principles of protection against each of these effects will be examined. At the same time, it will be shown how the measures used to provide protection from one particular effect can furnish protection against

[1] See the bibliography at the end of the chapter.

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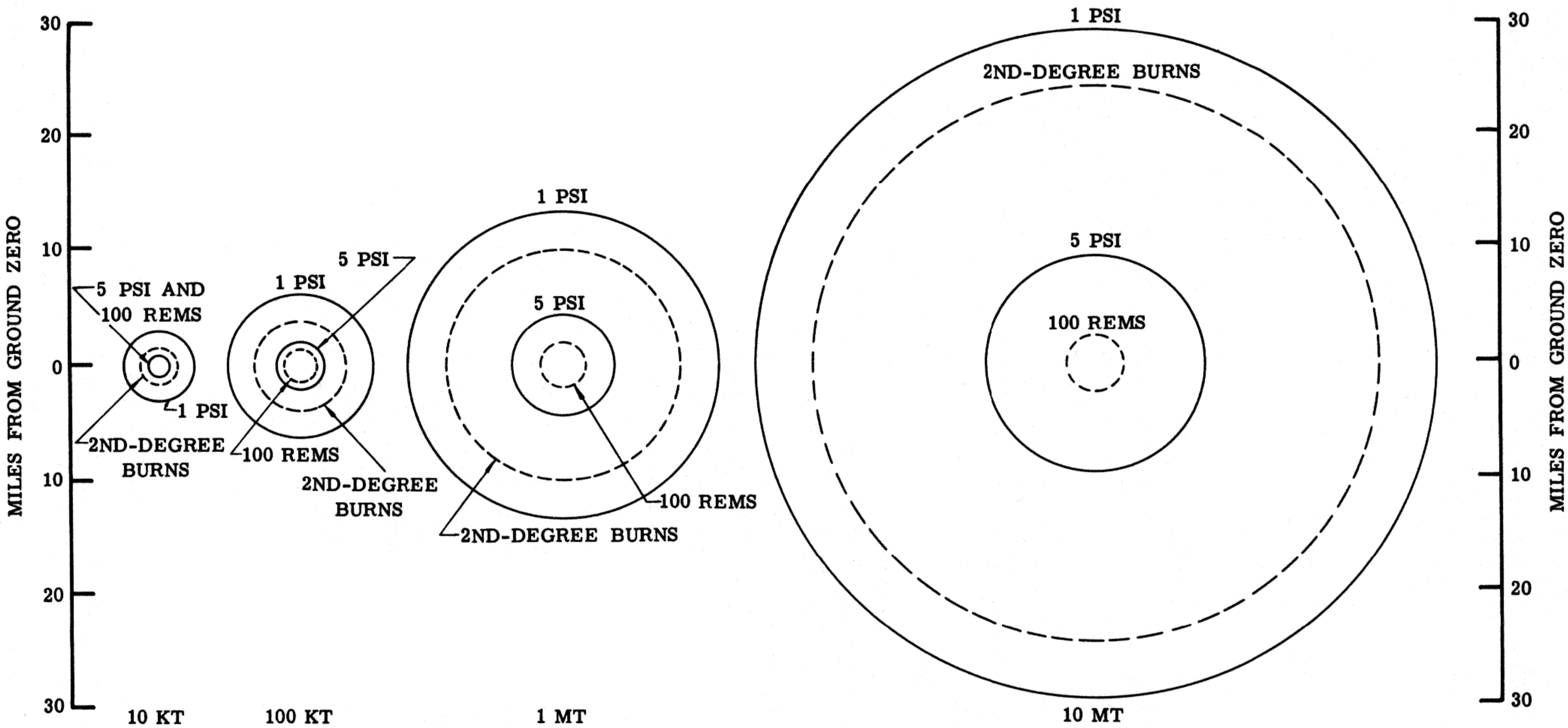
others, so that the problem is less complicated than it might at first appear. Finally, a brief discussion will be presented of the planning needed to implement the principles of protection so as to make them effective.

IMMEDIATE AND DELAYED EFFECTS

12.04 The effects of a nuclear explosion may be divided into two broad categories, namely, immediate and delayed. The immediate effects are those which occur within a few minutes of the actual explosion. These include air blast and ground shock, thermal radiation (light and heat), and initial nuclear radiation.

12.05 The delayed effects are associated with the radioactivity present in fallout and neutron-induced radioactivity. The early fallout from a surface burst will begin to reach the ground within a few minutes after the explosion at close-in locations, and at increasingly later times at greater distances from ground zero, depending on the effective wind speed and direction. At distances of several hundred miles from the explosion, the fallout may not commence until as late as 24 hours after the burst time. Furthermore, several hours may elapse between the time of arrival of the fallout at any point and the time when deposition is essentially complete. A significant early fallout is associated with a surface burst or a subsurface burst which vents to the atmosphere, but not with an air burst or with a completely contained underground burst. Neutron-induced radioactivity, apart from that in the weapons residues, extends only a short distance from ground zero and it decays more rapidly than fallout.

12.06 Except for a contained burst, all presently known nuclear weapons produce delayed (world-wide) fallout. However, this part of the fallout is generally not apparent until several weeks or months have elapsed; it will not be treated here, since the present discussion refers to protection which is effective at the time of, and soon after, an explosion.



Idealized ranges for effects of air burst with the heights of burst optimized to give the maximum range for each effect

casualties. Second-degree burns may be experienced at distances approaching those for 1 psi overpressure and less severe burns may be suffered at much greater distances from ground zero. Eye injury may also occur at even greater ranges and for high-altitude bursts of megaton weapons, this distance may be as much as several hundred miles. Furthermore, in dry, clear weather, many small fires would probably be ignited in newspapers and other thin combustible materials both within and outside of buildings.

Effective Protection Areas

12.11 In Japan, where little evasive action was taken, the survival probability depended upon whether the individual was outdoors or inside a building and, in the latter case, upon the type of structure. At distances between 0.3 and 0.4 mile (530 and 700 yards) from ground zero in Hiroshima the average survival rate, for at least 20 days after the nuclear explosion, was less than 20 percent. Yet in two reinforced-concrete office buildings, at these distances, almost 90 percent of the nearly 800 occupants survived more than 20 days, although some died later from radiation injury. Furthermore, of approximately 3,000 school students who were in the open and unshielded within a mile of ground zero at Hiroshima, about 90 percent were dead or missing after the explosion. But of nearly 5,000 students in the same zone who were shielded in one way or another, only 26 percent were fatalities. These facts bring out clearly the greatly improved chances of survival from a nuclear explosion that could result from the adoption of suitable warning and protective measures.

12.12 As a rough guide, the inner range at which protection in conventional structures could be achieved may be supposed to be that where the overpressure is 5 pounds per square inch and the outer range, beyond which casualties will be small *for an air burst*, is at 1 pound per square inch (or the limit for second-degree burns). As seen above, survival in Hiroshima was possible in buildings at such distances that the overpressure in the open was 15 to 20 pounds per square inch. The somewhat arbitrary choice of an overpressure of 5 pounds per square inch, which was experienced at a little over a mile from ground zero in Japan, is thus very conservative. In any case, it is evident from the circles in Fig. 12.08 that the area over which protection could be effective in saving lives is roughly eight to ten times as great as that in which the chances of survival are small.

12.17 The time sequence referred to in § 12.16 brings up another aspect of nuclear weapons effects that has a bearing on protection. Except very close to ground zero, even the immediate effects do not occur simultaneously. The first, almost instantaneous, indication of a nuclear explosion in the air or on the earth's surface is a brilliant flash of light. In many circumstances, it may be feasible, after observing the flash, to take some appropriate protective action that could greatly minimize the degree of injury suffered. At distances beyond those at which the immediate blast, thermal, and initial nuclear effects of the explosion are significant, there may be some time to make final preparations to decrease the early fallout.

12.18 As a general guide for planning purposes, it is useful to know the magnitudes of the respective immediate effects at a range of distances from an explosion of given yield. This information can be obtained from various figures and tables given in earlier chapters and can be identified from the list in the table of contents at the beginning of the book. A tabular summary of part of the data for air bursts, which may be more convenient for some purposes, is given in Table 12.18. The heights of burst are such as to maximize the various effects. An asterisk indicates that the particular distance is within the fireball; otherwise a blank space implies that the value is too small to be significant. The initial nuclear radiation doses are not given for distances of 5 miles or more for they are extremely small even for a 10-megaton explosion.

BLAST EFFECTS

Effects on Structures

12.19 Injury to individuals both inside and outside a structure may occur because of the blast damage to that structure. Persons in the interior of the building can be injured and trapped by collapse and fire, and those outside can be hurt by flying debris. For these and other reasons, an important aspect of protection is an understanding of the relative ability of different structures to withstand damage from air blast. Both the peak overpressure and the peak dynamic (or wind) pressure determine the amount of the damage, but for certain structures one or the other of these pressures has the dominant effect. For most office-type and residential buildings, including ordinary houses, the extent of destruction is mainly dependent on the peak overpressure, and an approximate correlation between the overpressure and the expected physical damage is given in Table 12.19.

TABLE 12.29—ARRIVAL TIME FOR PEAK OVERPRESSURE

Distance (miles)	Explosion yield				
	1 KT	*10 KT*	*100 KT*	*1 MT*	*10 MT*
			(*Time in seconds*)		
1	4. 3	3. 6	3. 7	2. 5	1. 5
2	>9	8. 1	7. 4	6. 5	5. 0
3	--------	>13	12	11	9. 5
5	--------	--------	21	20	16
7	--------	--------	>30	28	26
10	--------	--------	--------	42	37
20	--------	--------	--------	>90	83
30	--------	--------	--------	--------	>130

12.30 It is seen that at 10 miles from a 10-megaton air burst, which is within the area where protection against blast could be effective, some 37 seconds would elapse before arrival of the blast wave. If prompt action is taken, a person in a building could reach a position of the type indicated above. In the open, some protection against the blast may be obtained by falling prone, and remaining in that position until the wave has passed. In the prone position, with the head directly toward or directly away from the explosion, the area of the body exposed to the onrushing blast wave is relatively small and the danger of displacement is thereby decreased (cf. § 11.38).

the second thermal maximum. The elapsed times between the instant of the explosion and the second thermal maximum for air and surface bursts of various energy yields are recorded in Table 12.34. From this table it is seen that the prospects of being able to take evasive action are not good for air or surface bursts of low energy yield, but some possibility may exist for explosions in the megaton range.

TABLE 12.34

TIME TO SECOND THERMAL MAXIMUM

	Explosion yield				
	1 KT	*10 KT*	*100 KT*	*1 MT*	*10 MT*
Time (seconds)	0. 03	0. 1	0. 3	1. 0	3. 2

12.35. The major part of the thermal radiation travels in straight lines, and so any opaque object interposed between the fireball and the exposed skin will give some protection. This is true even if the object is subsequently destroyed by the blast, since the main thermal radiation pulse is over before the arrival of the blast wave.

12.36 At the first indication of a nuclear explosion, by a sudden increase in the general illumination, a person inside a building should immediately fall prone, as described in § 12.30, and, if possible, crawl behind or beneath a table or desk or to a planned vantage point. Even if this action is not taken soon enough to reduce the thermal radiation exposure greatly, it will minimize the displacement effect of the blast wave and provide a partial shield against splintered glass and other flying debris. An individual caught in the open should fall prone to the ground in the same way, while making an effort to shade exposed parts of the body. Getting behind a tree, building, fence, ditch, bank, or any structure which prevents a direct line of sight between the person and the fireball, if possible, will give a major degree of protection. If no substantial object is at hand, the clothed parts of the body should be used to shield parts which are exposed. There will still be some hazard from scattered thermal radiation, especially from high-yield weapons at long range, but the decrease in the direct radiation will be substantial.

12.37 Clothing of the proper kind provides good protection against flash burns. Materials of light color are usually preferable to dark materials because the former reflect the radiation. Clothing of dark shades absorbs the thermal radiation and may become hot enough to ignite, so that severe flame burns, which are more serious that the flash burns, may result. Woolen materials give better protection than those of cotton of the same color, and the heavier the fabric the

In Japan the fires were so numerous and spread so rapidly that it would have been beyond the capability of regular fire departments to deal with them even if the latter had survived the bombings. The training of private individuals in emergency methods of firefighting, such as were developed in Europe during World War II, is therefore desirable. By extinguishing small fires soon enough, the number of serious fires may be sufficiently small to be dealt with by professional firefighters.

12.42 Conventional methods for preventing the spread of large fires, by the use of natural and artificial fire breaks, were not too successful in Japan, for the reasons mentioned in § 7.72. Nevertheless, consideration should be given to the provision of adequate fire breaks and to the zoning and planning of urban areas. As seen in § 7.55, the potential for the development and spread of fires is greatest in wholesale distribution and slum residential areas. Dispersal and protection of utilities and emergency services should be included in such planning.

INITIAL NUCLEAR RADIATION

Effects on Personnel

12.43 The initial nuclear radiation consists of gamma rays and neutrons received during the first minute after the explosion. Doses of this radiation up to 100 rems, over the whole body, would have little or no immediate observable effects on exposed individuals. The only effect expected might be a slight feeling of fatigue in some people. Many persons receiving larger doses, up to 200 rems, would not be greatly affected by the radiation, except for blood changes. For the present purpose, however, it will be supposed that a whole-body dose of 100 rems will cause few, if any, casualties requiring medical attention. At the other extreme, it is probable that every person receiving 1,000 rems over the whole body will become sick within 4 hours (or less) of exposure and will die in 2 or 3 weeks. Between these extremes there is a great deal of variation in the expected effects on personnel, but at an exposure of around 400 to 500 rems, all will be nauseated and vomit on the first day, and most will require medical care. However at this exposure, at least one-half of the people will probably recover.

earth also helps in this connection; a 26-inch thickness of earth attenuates the radiation by a factor of about ten and 3 feet by about thirty.

12.46 The immediate evasive action suggested earlier for limiting the effects of thermal radiation and blast to a person in the open may assist, to a lesser extent, in reducing the dose of initial nuclear radiation. From high-yield weapons, in particular, a second or two elapses before much of the nuclear radiation is delivered at distances where survival is possible (§ 8.43). Table 12.46 gives the percentage of the total initial gamma-radiation dose received at given distances from 20-kiloton and 5-megaton explosions as a function of time. The total unshielded dose would be about 4,500 roentgens in each case.

TABLE 12.46

INITIAL GAMMA-RADIATION DOSE AS A FUNCTION OF TIME

Explosion yield	*Distance (miles)*	*Time (seconds)* 1	2	4	7	10	15	20
		Percentage of initial gamma-radiation dose delivered						
20 KT	0. 5	67	78	88	95	97	100	-----
5 MT	1. 5	5	17	43	76	90	98	100

12.47 As shown by the table, there is some possibility of reducing the radiation dose by immediate evasive action. However, from the numbers given above for the attenuation by concrete and earth, it is obvious that a nuclear radiation shield must be very massive if it is to be effective. Normal clothing, for example, will do little to attenuate initial nuclear radiation, although it may provide complete protection from thermal radiation. Another difficulty in connection with obtaining shelter in the open is the scattering of nuclear radiation, so that it may reach a person from many directions and not just along a direct line from the point of explosion.

RESIDUAL NUCLEAR RADIATION

FALLOUT HAZARD

12.48 The principal effects on personnel from residual radiation are similar to those from comparable doses of initial nuclear radiation as described in the preceding section. However, the hazards of exposure to residual radiation are entirely different from exposure to initial radiation and these hazards are described in this section.

12.49 Protection against residual nuclear radiation occupies a position of special significance. Because the early fallout can cover

an area much larger than that over which blast, thermal radiation, and initial nuclear radiation are significant, it is possible for people to become casualties at such distances from the explosion that the immediate effects are negligible or completely absent. As noted earlier, it is not feasible to state the degree of hazard from residual radiation in a reasonably accurate manner because it is so highly dependent upon conditions, especially wind speeds and directions over a considerable height. It is certain, however, that a surface burst in the megaton range will lead to contamination of very large areas by early fallout. This fallout will reach the ground very soon after the explosion at near distances, but at distances of several hundred miles, up to 24 hours may elapse before the fallout starts to arrive.

12.50 The early fallout hazard is of two main kinds: one results from the actual contact of the radioactive material with the skin, causing what are called "beta burns" produced by the action of the beta particles, and the second is due to the continuous exposure of the body to gamma rays, both direct and scattered, from fallout particles. It is with the second of these hazards that the discussion here will be mainly concerned. The protective measures for use against beta burns are chiefly associated with keeping the dust-like particles off the skin. If the fallout dust does get on the skin, it should be immediately washed off with soap and water. The possible hazard from entry of radioactive material into the body by ingestion will be considered later (§ 12.66 *et seq.*).

Induced Radioactivity

12.51 In addition to the radioactive fallout, there may be a residual radiation hazard near ground zero caused by induced activity resulting from the capture of neutrons by various elements in the soil, especially sodium and manganese. The induced-activity hazard may exist on the ground after an air burst when the initial fallout is virtually absent. However, this activity not only decays much more rapidly than does that from fallout, but it extends only a short distance (1 mile or less) from ground zero. Since the destruction in this area would be considerable, the only persons entering it for some time after the explosion should be rescue teams and others performing urgent missions. Such teams would be equipped with instruments to inform them of the radiation hazard.

Protective Measures

12.52 Assuming the population is to remain in the fallout area, and not be evacuated, it is necessary to obtain protection which

attenuates the gamma radiation. The basic principle to be borne in mind is that any massive or thick material will decrease the nuclear radiation level to some extent, whereas lighter construction, e.g., window areas, hollow, thin, or light walls, etc., permits the radiation to penetrate. A layer of concrete 8 inches thick or of earth 12 inches thick will yield an attenuation factor of 10; [2] doubling these thicknesses will increase the factor to 100. Thus, each extra foot of earth between an individual and the fallout will increase the protection factor tenfold. It should be remembered that scattered radiation will come from many directions, and so protection is necessary from all directions, either by the use of a mass of material or by distance.

12.53 Information has been published that describes procedures and standards for evaluating the potential of existing structures as fallout shelters and for modifying such structures to improve their effectiveness in this respect. The recommended procedures and standards may also be utilized in the design of new structures. Furthermore, instructions for building simple and effective fallout shelters are readily available. Basically, a fallout shelter is a structure with massive walls and ceiling. Practical materials of construction are earth, concrete, or solid masonry. Attenuation of the gamma radiation is provided by absorption in these materials and by the distance separating the fallout particles from the people in the shelter.

12.54 Since a shelter may have to be occupied continuously for periods as long as 2 weeks, until the natural decay of the radioactivity outside will allow the people to emerge, stocks of food and other supplies will be required. Where fallout arrives soon after the explosion, the early radiation dose rate will be high. It may then be necessary to wait several days before it is possible to come out of the shelter for more than a limited period without risking a radiation dose of sufficient magnitude to cause serious illness. In the path of the fallout, the early radiation levels will be lower at more distant points from the explosion, and the time necessary to occupy the shelter will be shorter, unless "hot spots" are present (§ 9.55). However, in any area where contamination is at all significant, it will probably be necessary to spend the first day or two after the burst sheltered from the residual gamma radiation. It is during the period immediately following the nuclear explosion, when the radiation level is at its highest, that protection is most important.

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[2] It should be noted that more than twice these thicknesses of concrete (18 inches) and of earth (26 inches) are required to attenuate the initial nuclear radiation to the same extent (§ 12.45) because the energy of the initial gamma rays is greater than in the residual (fallout) radiation.

12.55 A fallout shelter of the kind referred to in § 12.53 will provide a protection factor of about 200 from the residual radioactivity; in other words, the dose rate in the shelter will be only ½ percent of that measured outside at a height of 3 feet above the ground. Where a shelter is not available, a similar protection factor from radiation can be obtained in the following manner in a small area of the basement of a two-story house. A sturdy table is placed in a corner adjacent to an unexposed outer wall and covered with 10 to 12 inches of soil, sandbags, solid concrete block, etc., according to what is available. If there are no heavy partitions or walls near the corner of the basement chosen, a layer of sandbags or concrete blocks should be stacked along the walls up to the height of the material on top of the table. Within the area under the table, there will be a protective factor of at least 100 from fallout radiation. The disadvantage of this type of protection is that it is unlikely that stocks of food and water would be available within the shelter, so that it could not be occupied continuously for an extended period, as could the more permanent type outlined previously. In almost any house with a buried basement, having uniformly thick exterior walls, a protection factor of 20 to 40 is possible. The maximum protection can be obtained near the floor and in the corners of the basement adjacent to an unexposed outer wall.

12.56 Before leaving a shelter, either temporarily or permanently, it is highly desirable that the radiation dose rate, both in the immediate area of the shelter and in the surrounding vicinity, be known. Marked variations in fallout patterns have been observed in weapons tests, with unexpected areas (hot spots) of exceptionally high activity. Hence, it is not sufficient to know merely that a nearby location is relatively safe. Communications equipment, e.g., battery-powered radios, and radiation measuring instruments should be in shelters. Otherwise it will not be possible to obtain information on radiation dose rates in the locality and in the immediate vicinity of the shelter, particularly at early times when high radiation levels will prevent radiation monitors from moving safely and freely about the community. As a rough rule-of-thumb, it may be stated that for every sevenfold increase in time, the radiation level will decrease by a factor of 10, provided the fallout is complete. For example, the radiation level at the end of 7 days will have fallen to roughly one-tenth of that at the end of 1 day. At the end of 49 days, it will have decreased by a factor of 100, etc.[3]

12.57 It is appropriate to mention here that whether or not fallout is visible to the eye, its measurement requires the use of suitable

[3] The rule is applicable to any unit of time; thus at 7 hours the residual radiation level will be one-tenth of that at 1 hour, at 14 hours it will be one-tenth of that at 2 hours, and so on, provided the fallout is complete at both times.

instruments sensitive to nuclear radiations. Some, although perhaps not all, of the fallout in the Marshall Islands, after the test explosion of March 1, 1954 (§ 9.100 *et seq.*), could be seen as a white powder or dust. This was due, partly at least, to the light color of the calcium oxide or carbonate of which the particles were mainly composed. It is probable that whenever there is sufficient fallout to constitute a hazard, the dust will be visible. Nevertheless, continuous monitoring with instruments for radioactive contamination would appear to be essential in all areas in the vicinity of the burst.

Radiological Surveys

12.58 As soon after a nuclear explosion as conditions permit, radiological monitoring surveys will have to be initiated for the purpose of developing information on the extent and levels of the contamination. At early times in heavily contaminated areas, where dose rates will be very high, only the most limited amount of monitoring can be accomplished by individuals with hand-carried instruments. In these circumstances, some kind of remote radiation monitoring equipment may be necessary. This will permit the monitor to remain within the shelter while taking readings of the dose rate outside.

12.59 The most rapid method for obtaining radiation levels in a large area is by aerial survey. Because of their long range in air, gamma rays can be detected by sensitive instruments at a height of a few thousand feet. Low-flying airplanes or helicopters, carrying suitable radiation instruments for measuring dose rates, can survey large areas unimpeded by damage on the surface and by impassable streets and roads. Moreover, by making initial flights at an altitude of 1,600 feet or so, the dose rates are only about 1 percent of those on the ground, so that the hazard to the monitor is decreased accordingly.

12.60 The dose rates measured at an altitude must be multipled by an appropriate factor to give the approximate dose rates near the ground. This factor will depend primarily on the height above the ground and nature of the terrain. In the absence of more specific information, the data in Fig. 9.181 may be used to estimate the attenuation factor at a known altitude with reference to that at a height 3 feet above the ground.

12.61 The aerial survey is important because it can be made readily and can provide information which might be impossible to obtain in any other way at the time of interest. Nevertheless, such a survey can serve only as a rough guide and should be made only after all the early fallout is out of the air and on the ground.

12.78 In the event that shelters are not available, certain evasive actions may prove helpful at distances where the immediate effects are least severe. By instantly falling prone and covering exposed portions of the body or getting behind opaque objects, much of the thermal radiation may be avoided, especially in the case of large-yield weapons. Under no circumstances should an individual look in the direction of the fireball. Staying behind thick walls or lying in a deep ditch may help to avoid initial nuclear radiation. All of the above actions will also help to decrease the possible danger from the blast wave. Moreover, persons should avoid areas which have frangible materials, such as window glass, plaster, etc., which may become flying debris by the action of the blast.

12.79 After the immediate effects of the nuclear explosion are over, certain acts are required to minimize the hazards of the early fallout and from the fires which may result from thermal radiation and secondary blast effects. First, if small fires can be quickly extinguished, extensive conflagrations may be prevented. This must be accomplished before the arrival of the fallout or in areas of low radioactivity levels. Some protection from the fallout may be secured in the basements of buildings or in a quickly constructed shelter, such as is described in § 12.55. It is important to keep from coming into physical contact with the fallout particles, and to prevent contamination of food and water sources. Monitoring equipment should be used to determine areas which have safe radiation levels and decontamination efforts can proceed to recover necessary equipment, buildings, and areas.

CONCLUSION

12.80 Much of the discussion presented in earlier sections of this chapter have been based, for simplicity, on the effects of a single weapon. It must not be overlooked that in a nuclear attack some areas may be subjected to several bursts. The basic principles of protection would remain unchanged, but protective action against *all* the effects of a nuclear explosion—blast, thermal radiation, initial nuclear radiation, and fallout—would become even more important. There is a good possibility that many people would survive a nuclear attack and this possibility would be greatly enhanced by utilizing the principles of protection in preattack preparations and planning, in taking evasive action at the time of an attack, and in determining what should be done in the recovery phase after the attack.

ORNL-5037

NUCLEAR WAR SURVIVAL SKILLS

Cresson H. Kearny

Date Published—September 1979

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830

IMPORTANCE OF ADEQUATE WARNING

When Hiroshima and Nagasaki were blasted by the first nuclear weapons ever to be used in war, very few of the tens of thousands of Japanese killed or injured were inside their numerous air raid shelters. The single-plane attacks caught them by surprise. People are not saved by having shelters nearby unless they receive warning in time to reach their shelters—and unless they heed that warning.

TYPES OF WARNINGS

Warnings are of two types, strategic and tactical.

- **Strategic warning** is based on observed enemy actions that are believed to be preparations for an attack. For example, we would have strategic warning if powerful Russian armies were advancing into western Europe and Soviet leaders were threatening massive nuclear destruction if the resisting nations should begin to use tactical nuclear weapons. With strategic warning being given by news broadcasts and newspapers over a period of days, Americans in areas that are probably targeted would have time to evacuate. Given a day or more of warning, tens of millions of us could build or improve shelters and in other ways improve our chances of surviving the feared attack. By doing so, we also would help decrease the risk of attack.

- **Tactical warning** of a nuclear attack on the United States would be received by our highest officials a few minutes after missiles or other nuclear weapons had been launched against our country.

Most of the knowledge about beta burns on human skin was gathered as a result of an accident during the largest U.S. H-bomb test in the tropical Pacific. Winds blew the fallout in a direction not anticipated by the meteorologists. Five hours after the multimegaton surface burst, some natives of the Marshall Islands noticed a white powder beginning to be deposited on everything exposed, including their bare, moist skin. Unknown to them, the very small particles were fresh fallout. (Most fallout is sand-like, but fallout from bursts that have cratered calcareous rock, such as coral reefs and limestone, is powdery or flakey, and white.) Since the natives knew nothing about fallout, they thought the white dust was ashes from a distant volcanic eruption. For two days, until they were removed from their island homes and cared for by doctors, they paid practically no attention to the white dust. Living in the open and in lightly constructed homes, they received from the fallout all around them a calculated gamma-ray dose of about 175 R in the two days they were exposed.

The children played in the fallout-contaminated sand. The fallout on these islanders' scalps, bare necks, and the tops of their bare feet caused itching and burning sensations after a time. Days later, beta burns resulted, along with extreme discoloration of the skin. Beta burns are not deep burns; however, it took weeks to heal them. Some, in spite of proper medical attention, developed into ulcers. (No serious permanent skin injury resulted, however.)

SKIN BURNS FROM HEATED DUST (THE POPCORNING EFFECT)

When exposed grains of sand and particles of earth are heated very rapidly by intense thermal radiation, they explode like popcorn and pop up into the air. While this dust is airborne, the continuing thermal radiation heats it to temperatures that may be as high as several thousand degrees Fahrenheit on a clear day in areas of severe blast. Then the shock wave and blast winds arrive and can carry the burning-hot air and dust into an open shelter. Animals inside open shelters have been singed and seriously burned in some of the nuclear air-burst tests in Nevada.

Thus Japanese working inside an open tunnel-shelter at Nagasaki within about 100 yards of ground zero were burned on the portion of their skin that was exposed to the entering blast wind, even though they were protected by one or two turns in the tunnel. (None of these Japanese workers who survived the blast-wave effects had fatal burns or suffered serious radiation injuries, which they certainly would have suffered had they been outside and subjected to the thermal pulse and the intense initial nuclear radiation from the fireball.)

Experiments conducted during several nuclear test explosions have established the amount of thermal radiation that must be delivered to exposed earth to produce the popcorning effect.

If Americans would learn to use skillfully the ordinary clothing, towels, cloth, newspapers, and paper bags in their homes, they could keep warm enough to stay healthy—even under much colder conditions than they believe endurable without specialized outdoor winter clothing. Efficient cold-weather clothing can be improvised if the following ways of conserving body heat are understood and used:

- **Trap "dead" air.** Covering enough of your body with a thick layer of trapped "dead" air is the basic requirement for keeping warm.

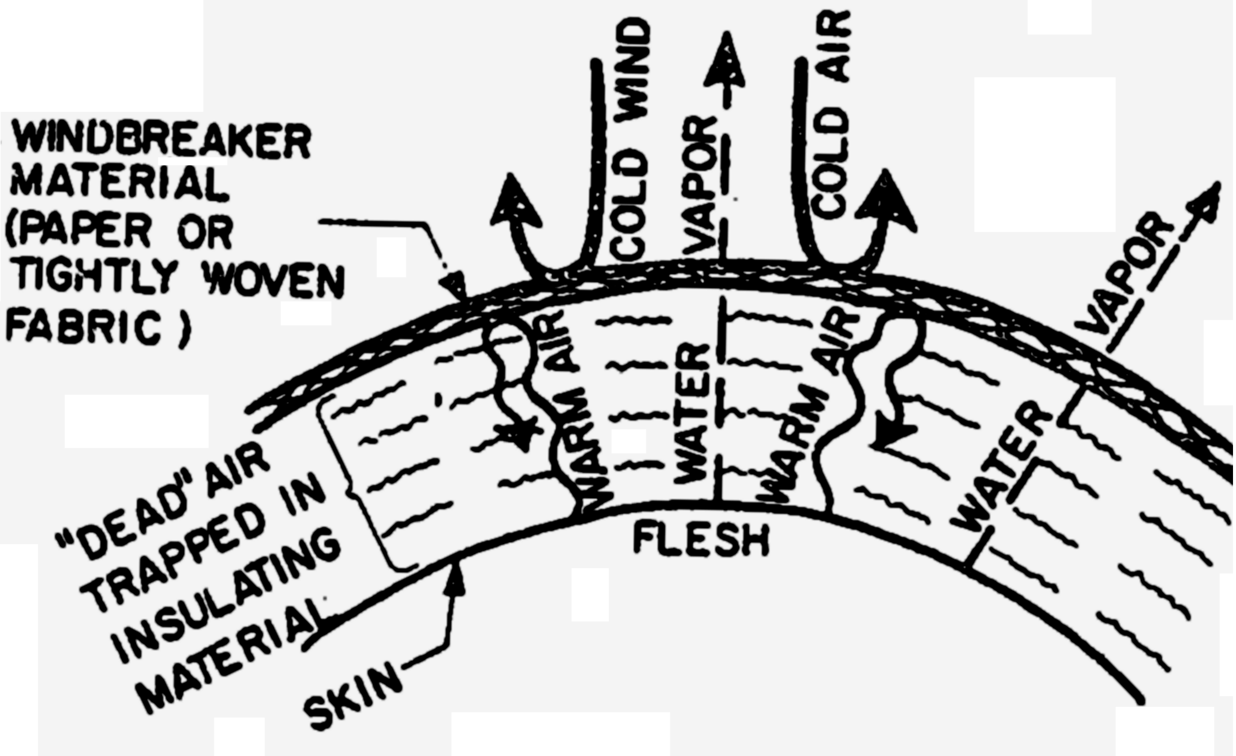


Fig. 15.1. Efficient body insulation.

- **Use windbreaker materials.** An outer windbreaker layer of clothing that is essentially air-tight, such as a brown paper bag worn over a knit wool cap, prevents the escape of warmed air and results in an insulating layer of trapped "dead" air. A single layer of good windbreaker material also prevents cold outside air from being blown into the insulating material and displacing warmed air (Fig. 15.1).

Se~~cr~~et

DIRECTORATE OF
INTELLIGENCE

Intelligence Report

Civil Defense in the Soviet Union

Se~~cr~~et

Copy No. 213

May 1969

CENTRAL INTELLIGENCE AGENCY
Directorate of Intelligence
15 May 1969

INTELLIGENCE REPORT

Civil Defense in the Soviet Union

Summary

Soviet political and military leaders at the 23rd Party Congress in 1966 reaffirmed their belief in the importance of a vigorous civil defense program. Since then, there has been a general rise in the level of civil defense activity in the Soviet Union.

In part the renewed emphasis reflects a conviction that a strong civil defense posture would help the USSR survive a nuclear war, but beyond that it also serves as a means for instilling a greater degree of patriotism and discipline in the populace. The regime's growing concern over the danger of liberal influences has stimulated increased reliance on paramilitary-type programs for large-scale indoctrination.

No other country has informed its people as thoroughly on the effects of nuclear, biological, and chemical weapons. Soviet citizens now are engaged in the sixth compulsory civil defense instruction program since 1955, and civil defense has become a required subject in elementary and secondary schools throughout the country. Workers are also participating in compulsory training. An extensive network of staff schools trains leaders for civil defense duties. The effect of all this indoctrination cannot be measured, but its pervasiveness has probably conditioned most of the populate to follow orders and take self-help measures in an emergency.

Note: This report was produced solely by CIA. It was prepared by the Office of Strategic Research and coordinated with the Office of Current Intelligence and Economic Research.

O. Tolstikov, Colonel General of the Air Force,
"United States Civil Defense," in
The Nuclear Age and War (Iadernyi vek i voina),
edited by A. A. Grechko,
Marshal of the Soviet Union,
Moscow, Izvestiia Publishing
House, 1964, pp. 123-132;
translated from the Russian
by Nadia Derkach, the RAND
Corporation, December, 1965

LT-65-106

It is clear that civil defense will be that much stronger if the moral and political unity of the citizens is strong and the citizens are rallied around the true ideas which can inspire people to heroic deeds and sacrifices. Capitalist states lack this fundamental principle in the organization of civil defense since their imperialist aims are in irreconcilable contradiction to the interests of the toiling masses.

Of course, the people in the capitalist countries will also strive to protect their families and their kin from nuclear death and their property from destruction. That is the law of life. However, the imperialists will not be able to create a strong, monolithic civil defense.

The difficulties of United States civil defense in staffing its forces are further aggravated by the fact that the population has been frightened by the horrors of nuclear war. The fear which has been instilled into Americans turns like a boomerang against those who fanned it.

The October 1962 days of the Caribbean crisis clearly illustrated the complete inability of U. S. civil defense to carry out its assignment.

Cristy, G. A. and C. H. Kearny, Expedient Shelter Handbook, ORNL-4941, Oak Ridge National Laboratory, Oak Ridge, Tennessee, August 1974.

EXPEDIENT SHELTER HANDBOOK

The decade of the seventies has already introduced many tremendous changes in the strategic situation. The present clear and admitted superiority of the Soviet Union both in weapons and in weight of their missile force is a sharp contrast to the massive superiority of the U.S. in nuclear weapons in the fifties and early sixties.

However, the Soviet Union has done more than achieve a state of superiority in nuclear weapons (a condition which has been accepted by the U.S. in the Interim Agreement on Offensive Weapons in conjunction with the Strategic Arms Limitation Treaty (SALT); the Soviet Union has also developed a strategic evacuation plan which can have a vital impact upon the strategic balance, especially when this balance depended for so long upon an assured destruction policy. The Soviet evacuation plan is a well organized and sophisticated plan based upon a clear statement of Soviet nuclear policy. The Soviet Union does not subscribe to the doctrine that nuclear war means the end of mankind. On the contrary, it instructs and prepares its citizens on how to survive such a war. Marshal V. I. Chuykov puts it this way:

> "Without slighting the serious consequences of a possible war, we should in all responsibility state that there is no poison for which there cannot be an antidote nor can there be a weapon against which there is no defense. Although the weapons we have examined are called mass weapons, with the knowledge and skillful use of modern defense measures they will not affect masses, but only those who neglect the study, mastery, and use of these measures."

> "Protection of the population is implemented by dispersing and evacuating the people to outlying areas and providing them protective shelters and personal means of protection."

—— Marshal V. I. Chuykov, "Civil Defense as Common Concern," *Nauka i Zhizn*, (Science and Life), No. 1, 1969.

REVIEW: CIVIL DEFENSE TEXT (1986)

Moscow VOYENNYYE ZNANIYA in Russian No 3, 1987 p 41

[Review by N. Korchagina of textbook "Grazhdanskaya Oborona" [Civil Defense] by V.G. Atamanyuk, L.G. Shirshev and N.I. Akimov, edited by D.I. Mikhaylik, Moscow, Vysshaya shkola, 1986, 207 pages]

[Text] This textbook on civil defense for higher technical educational institutions was published late last year. The authors developed this book under a new student training program.

Many of the graduates will become commanders of formations or workers of civil defense services, depending on the specialty obtained. The primary task of the VUZ is to train them in such a manner that they can confidently and competently carry out civil defense measures at those installations where they will later work.

The textbook thoroughly examines questions of the effects of weapons of mass destruction on industrial installations and problems of increasing the stability of operations during wartime. It tells in detail, using specific examples, of the methods for assessing the radiation and chemical situation.

Considerable space is given to protecting the population from weapons of mass destruction and performing rescue and emergency repair work both in the centers of destruction and when mopping up the after-effects of natural disasters, major accidents, and catastrophes.

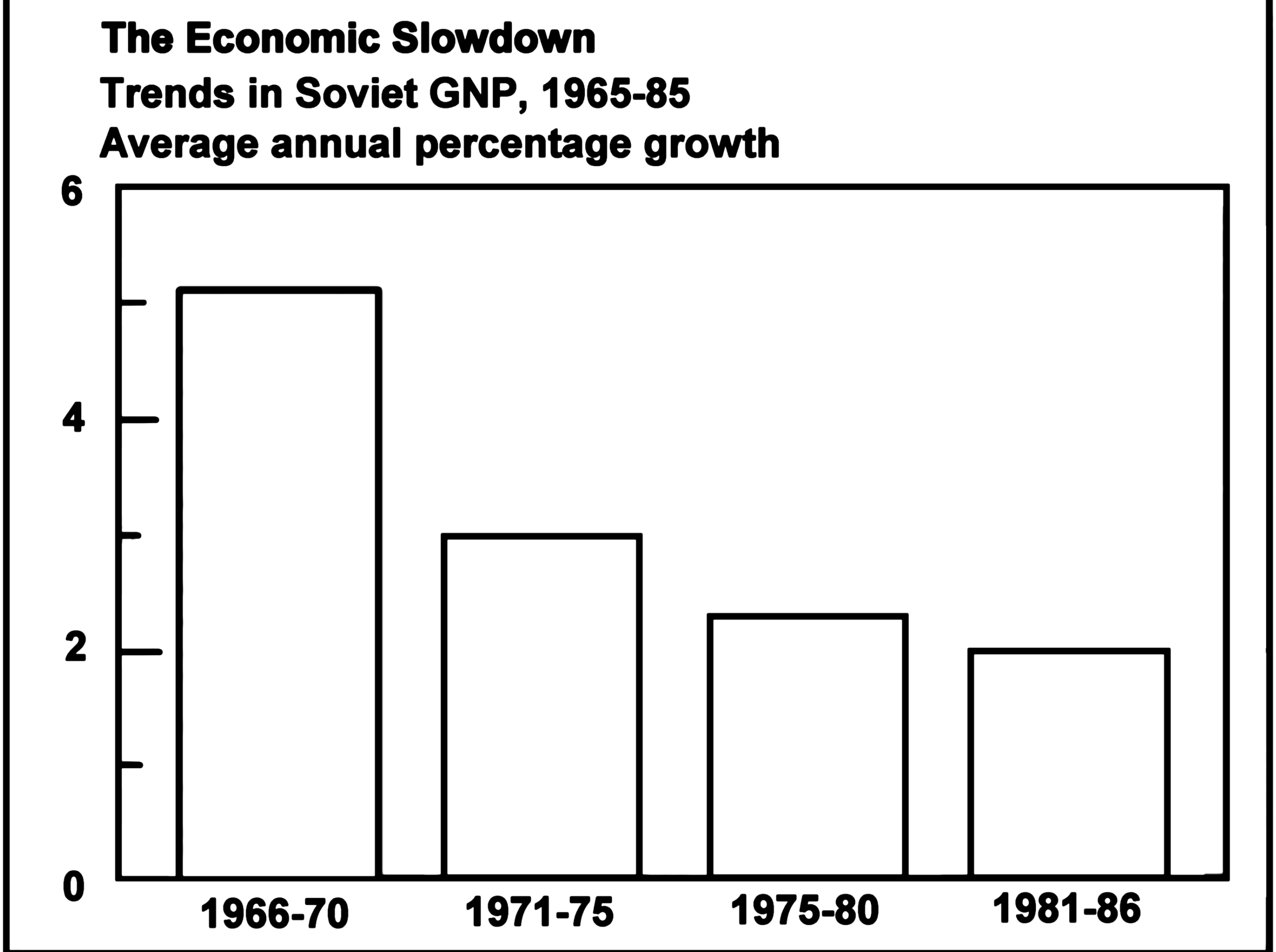
Materials are set forth well concerning the forms and methods of instructing the population on civil defense, the fundamentals of organizing political educational work, and the moral and psychological training of personnel of formations.

Each of the textbook's sections is illustrated with drawings, figures, diagrams, and graphs.

The training aid has five attachments which cite examples of calculations of parameters of the casualty-producing elements of a nuclear explosion and the loads created by the blast wave, as well as information on the radiation-resistance of materials and components of electronic and electrooptical equipment. In addition, two tables give the technical specifications of modern missiles and strategic bombers of the air forces of the United States, Great Britain, and France, making it possible to present clearly all the basic parameters of these weapons.

Gorbachev's Economic Program: Problems Emerge

DDB-1900-187-88
June 1988



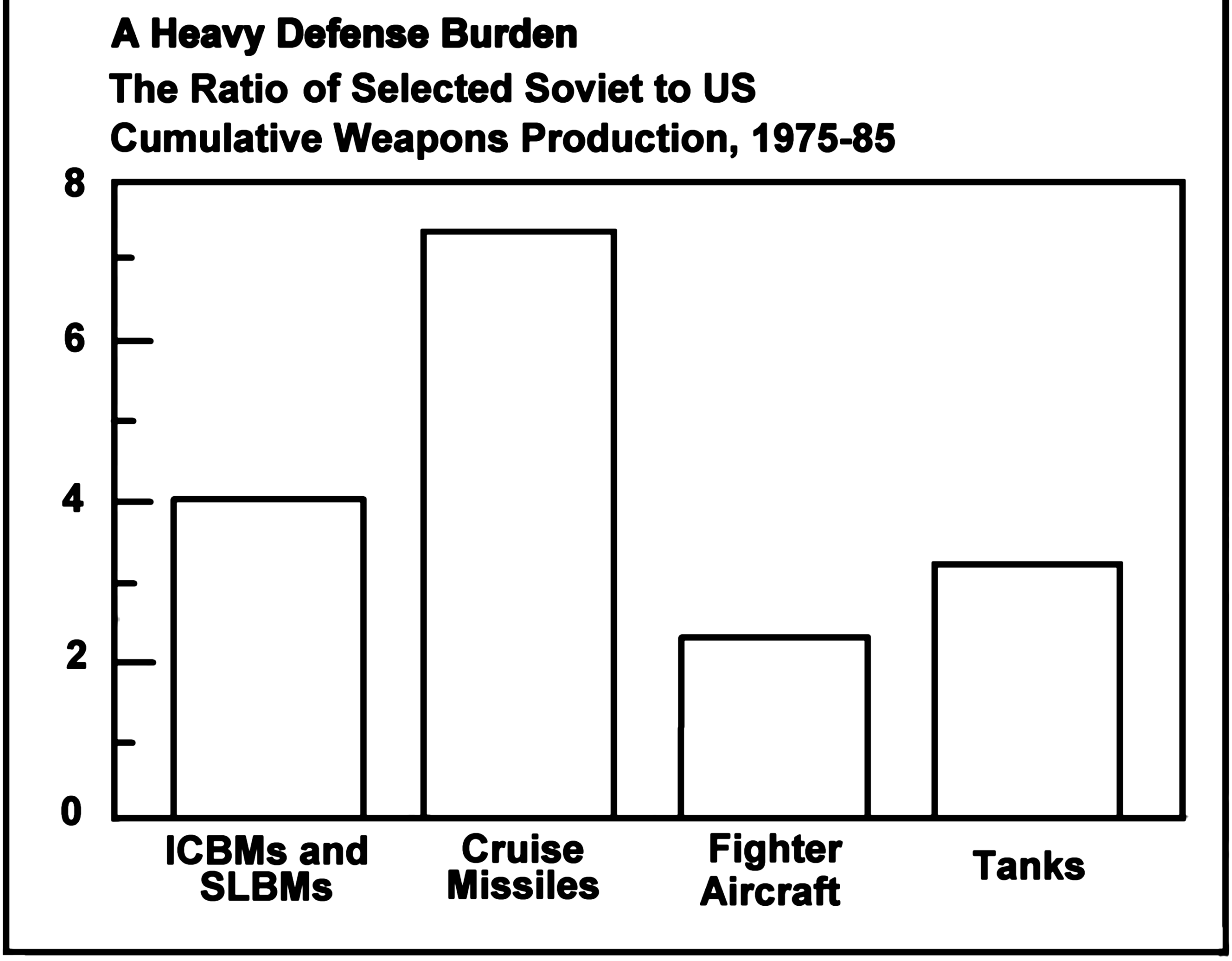


Figure 1. Gorbachev's Domestic Imperative

SOVIET MILITARY POWER

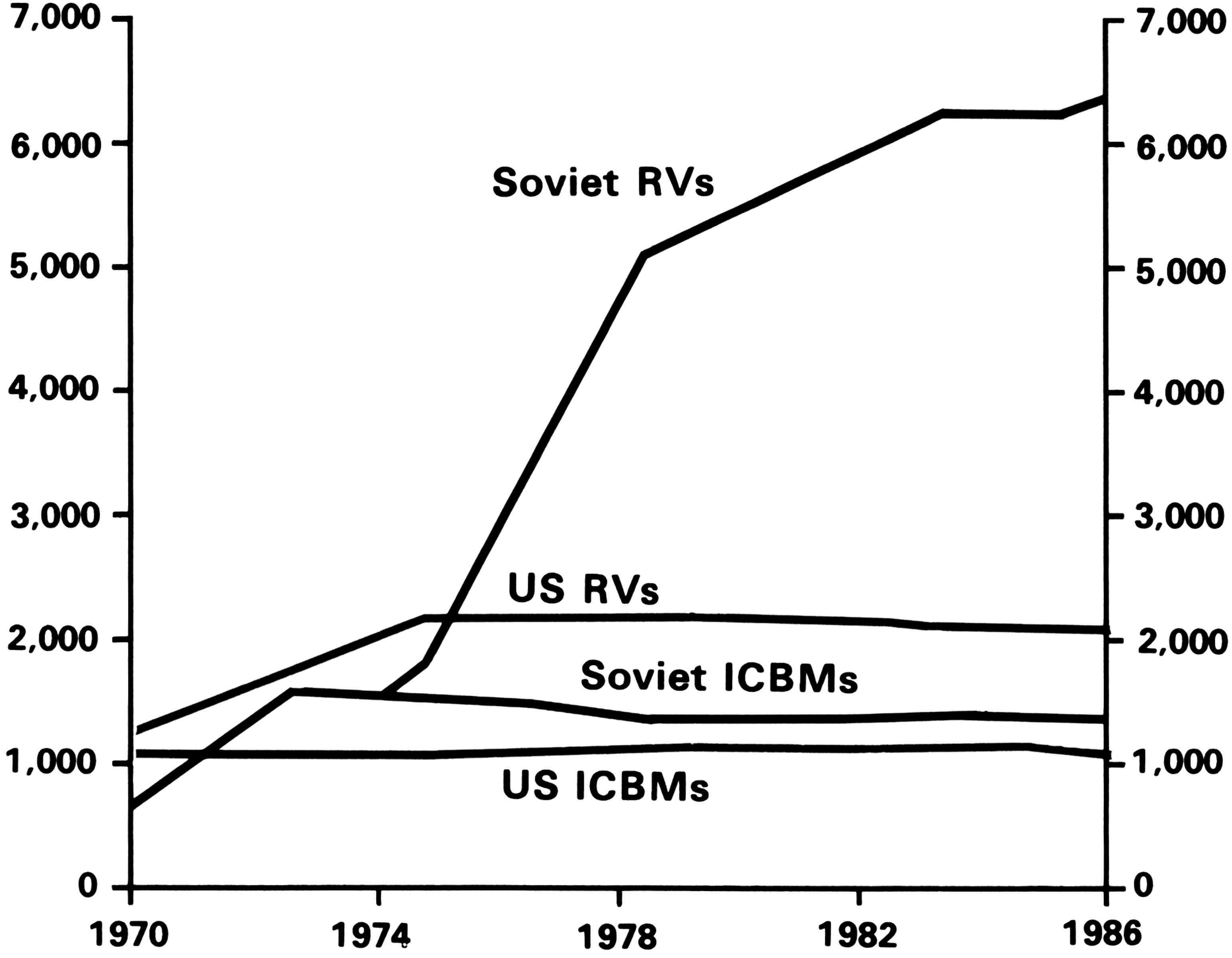
1986

SOVIET MILITARY POWER

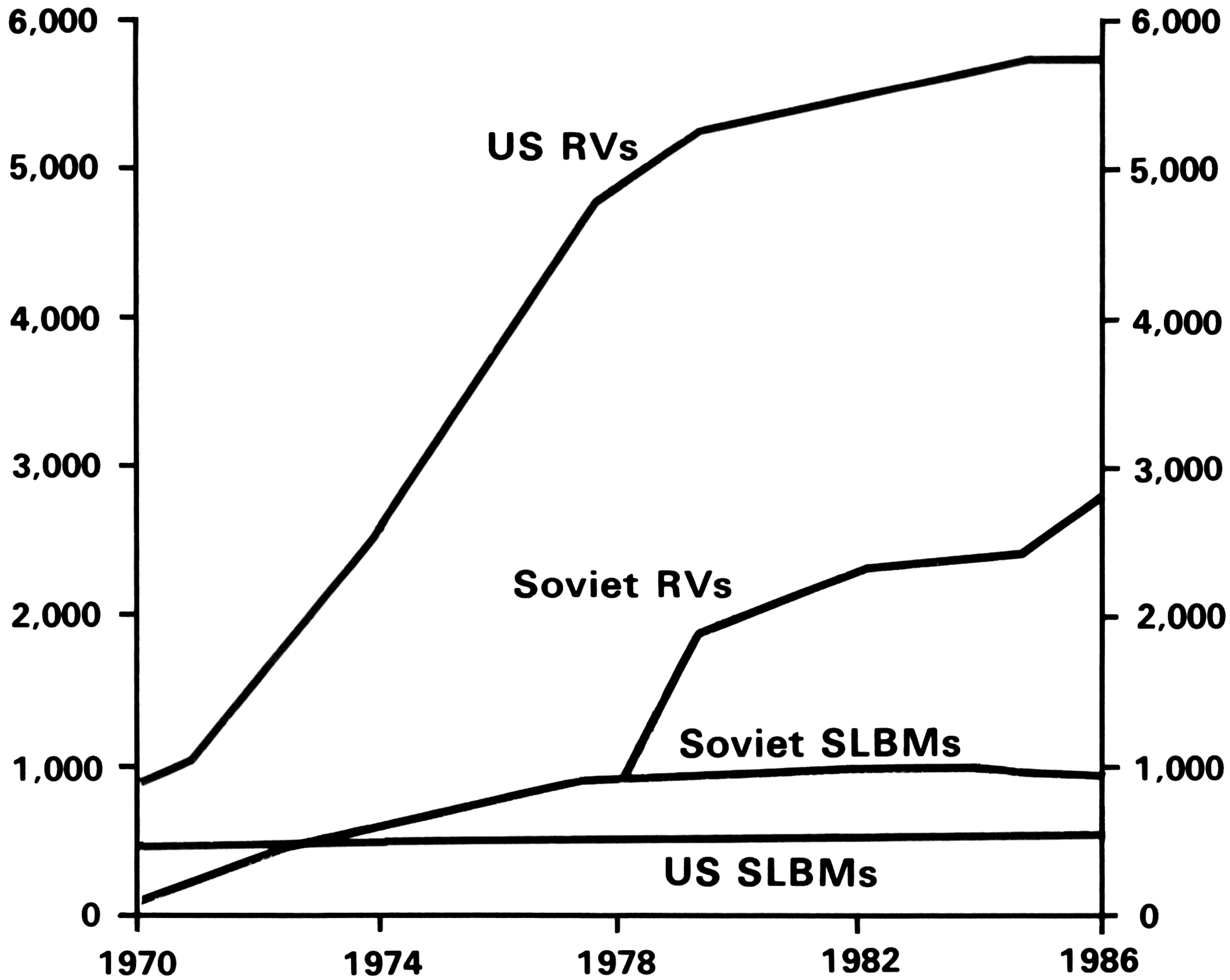
First Edition	September 1981
Second Edition	March 1983
Third Edition	April 1984
Fourth Edition	April 1985
Fifth Edition	March 1986

For sale by Superintendent of Documents, US Government
Printing Office, Washington DC 20402

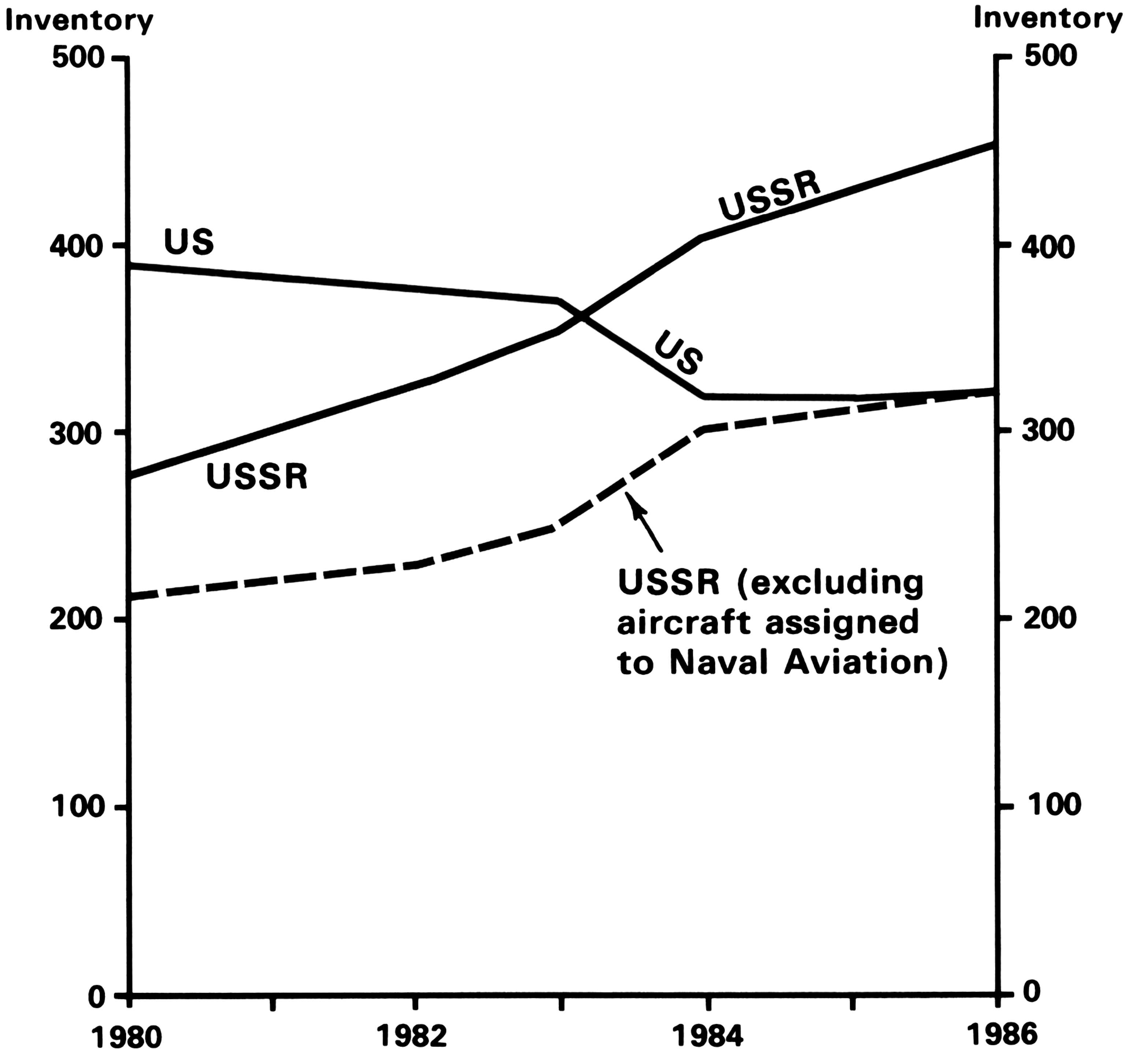
US and Soviet ICBM Launcher and Reentry Vehicle (RV) Deployment 1970-1986



US and Soviet SLBM Launcher and Reentry Vehicle (RV) Deployment 1970-1986

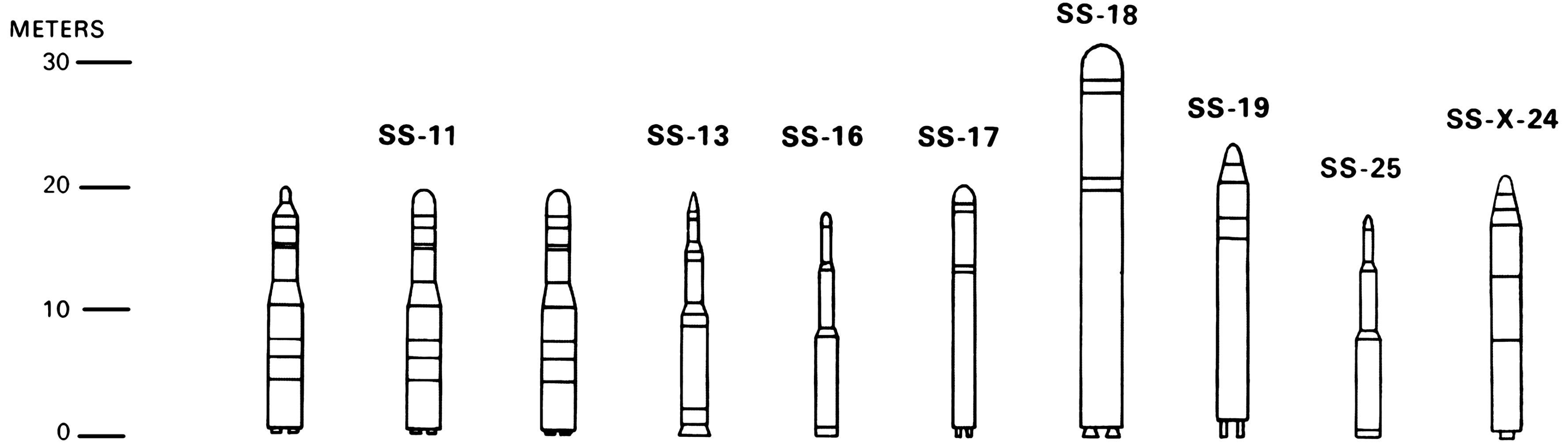


US and Soviet Intercontinental-Capable Bombers[1]



[1] US forces include B-52, FB-111, and B-1B; Soviet forces include BEAR, BISON, and BACKFIRE.

USSR ICBMs



	SS-11 MOD 1	SS-11 MOD 2	SS-11 MOD 3	SS-13 MOD 2	SS-16	SS-17 MOD 3	SS-18 MOD 4	SS-19 MOD 3	SS-25	SS-X-24
NUMBER DEPLOYED	28	420		60	Undetermined	150	308	360	70 +	In Development/ Testing
WARHEADS	1	1	3 MRVs	1	1	4 MIRVs	10 + MIRVs	6 MIRVs	1	Up to 10 MIRVs
MAX RANGE (KM)	11,000	13,000	10,600	9,400	9,000	10,000	11,000	10,000	10,500	10,000
LAUNCH MODE	Hot	Hot	Hot	Hot	Cold	Cold	Cold	Hot	Cold	Cold

US ICBMs

	TITAN II	MINUTEMAN II	MINUTEMAN III	PEACEKEEPER
NUMBER DEPLOYED	17*	450	550	In Development
WARHEADS	1	1	3	Up to 10
MAX RANGE (KM)	12,000	12,500	11,000 +	11,000 +
LAUNCH MODE	Hot	Hot	Hot	Cold

* As of early 1986

Robert Scheer

WITH ENOUGH SHOVELS: Reagan, Bush & Nuclear War

"Dig a hole, cover it with a couple of doors and then throw three feet of dirt on top... It's the dirt that does it... if there are enough shovels to go around, everybody's going to make it."

—T. K. Jones, Deputy Under Secretary of Defense for Strategic and Theater Nuclear Forces

"President Ronald Reagan had been in office less than a year when he approved a secret plan for the United States to prevail in a protracted nuclear war. This secret plan, outlined in a so-called National Security Decision Document, committed the United States for the first time to the idea that a global nuclear war can be won."

With these words Robert Scheer, the distinguished national reporter for the *Los Angeles Times*, begins this astonishing revelation of how a handful of Cold War ideologues—led by the President himself—have reversed the longstanding American assumption that nuclear war means mutual suicide.

Scheer reveals that President Reagan finds it "ridiculous" to assume that nuclear war means mutual destruction.

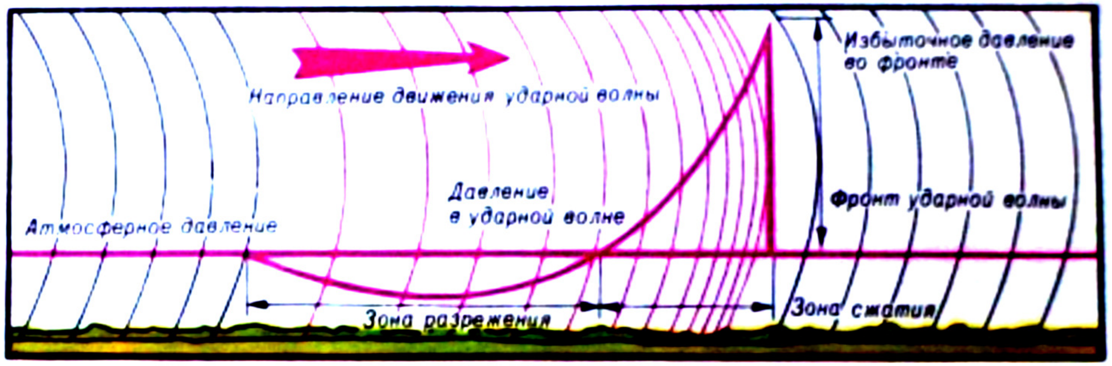
Robert Scheer's aim in *With Enough Shovels* is to expose the deadly course on which we are now embarked, a course that categorically rejects the strategic assumptions that prevailed from Presidents Eisenhower through Carter and that sustained the Nixon-Kissinger program of détente—a program which our current leaders call "appeasement." Instead they have chosen to pursue nuclear brinksmanship. As Richard Perle, the man whom President Reagan appointed Assistant Secretary of Defense for International Security Policy, told Scheer, "I've always worried less about what would happen in an actual nuclear exchange than the effect that the nuclear balance has on our willingness to take risks in local situations."

ROBERT SCHEER is a national reporter for the *Los Angeles Times* and has also written frequently for *Esquire*, the *Washington Post* and *Playboy*, where he conducted the interview in which Jimmy Carter revealed the lust in his heart.

УДАРНАЯ ВОЛНА

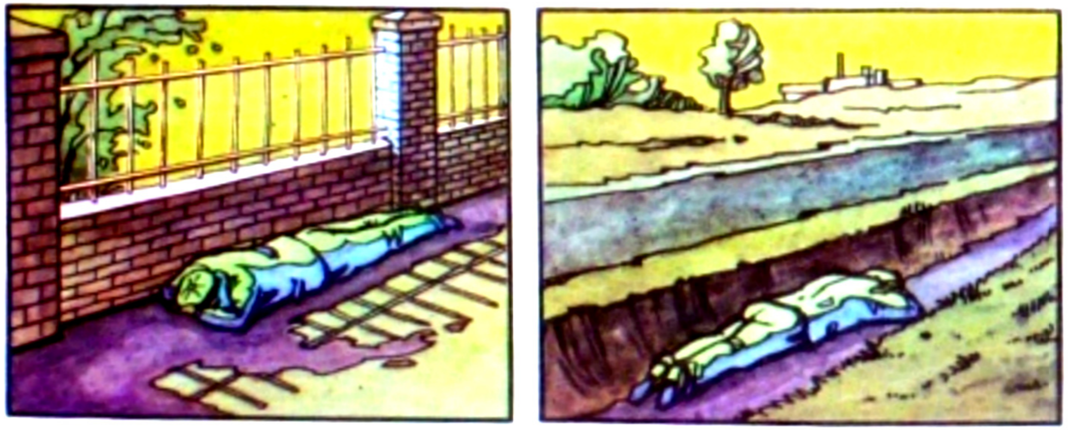
УДАРНАЯ ВОЛНА ЯВЛЯЕТСЯ ОСНОВНЫМ ПОРАЖАЮЩИМ ФАКТОРОМ ЯДЕРНОГО ВЗРЫВА. ОНА ВЫЗЫВАЕТ РАЗЛИЧНЫЕ ПО ХАРАКТЕРУ И ТЯЖЕСТИ ПОРАЖЕНИЯ ЛЮДЕЙ И ЖИВОТНЫХ, РАЗРУШАЕТ ЗДАНИЯ, СООРУЖЕНИЯ. С УДАЛЕНИЕМ ОТ ЦЕНТРА (ЭПИЦЕНТРА) ВЗРЫВА РАЗРУШИТЕЛЬНАЯ СИЛА УДАРНОЙ ВОЛНЫ ОСЛАБЕВАЕТ

СТЕПЕНЬ ПОРАЖЕНИЯ И РАЗРУШЕНИЯ УДАРНОЙ ВОЛНОЙ ЗАВИСИТ ОТ МОЩНОСТИ БОЕПРИПАСА, ВИДА И РАССТОЯНИЯ ОТ ЦЕНТРА (ЭПИЦЕНТРА) ВЗРЫВА, КОНСТРУКЦИИ И РАСПОЛОЖЕНИЯ ЗДАНИЙ И СООРУЖЕНИЙ, ПОЛОЖЕНИЯ ЛЮДЕЙ, ТЕХНИКИ ВО ВРЕМЯ ВОЗДЕЙСТВИЯ УДАРНОЙ ВОЛНЫ, РЕЛЬЕФА МЕСТНОСТИ И ДРУГИХ ФАКТОРОВ

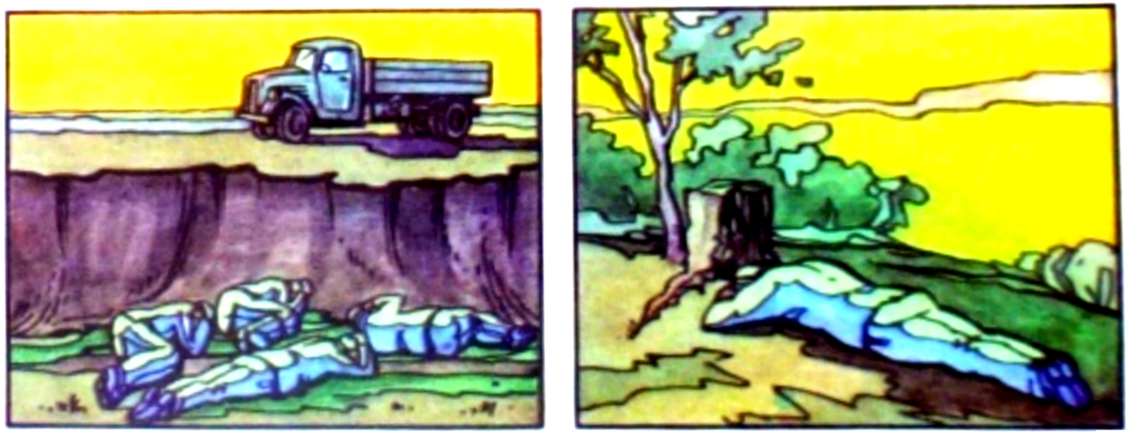


Ударная волна представляет собой область резкого сжатия воздуха, распространяющегося со сверхзвуковой скоростью во все стороны от центра взрыва

Очаг ядерного поражения в зависимости от давления во фронте ударной волны условно делится на зоны разрушений



Убежища защищают от воздействия ударной волны, а укрытия ослабляют ее воздействие



На значительном расстоянии от места взрыва защитой могут служить рельеф местности и местные предметы

Soviet textbook "Civil Defence", issued for Institutions of Higher Education, 288 pp., Published by Vysshaya Shkola, Moscow, 1987.

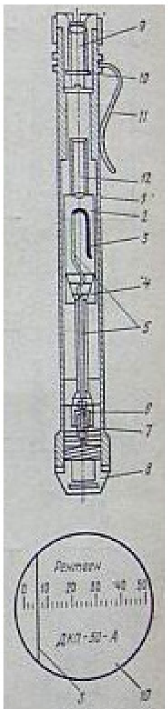


Рис. 17

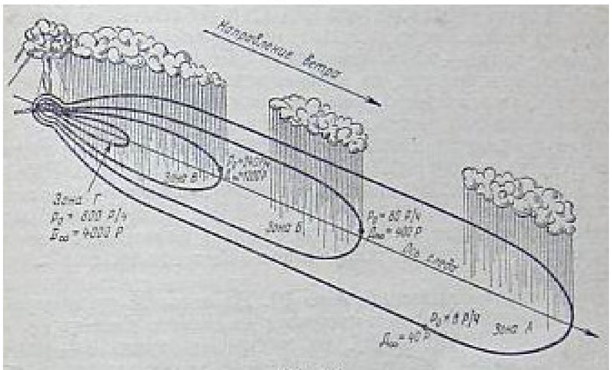
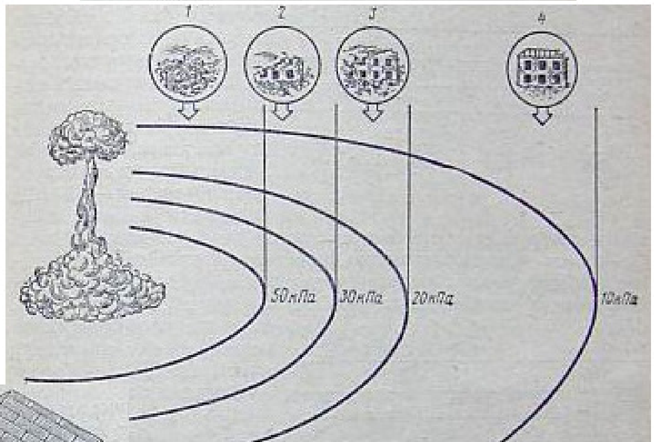


Рис. 12

$$P_t = P_0 \left(\frac{t}{t_0}\right)^{-1,2} \quad \text{или} \quad P_t = P_0 K_t, \qquad (12)$$



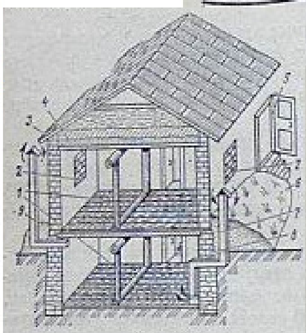


Рис. 24

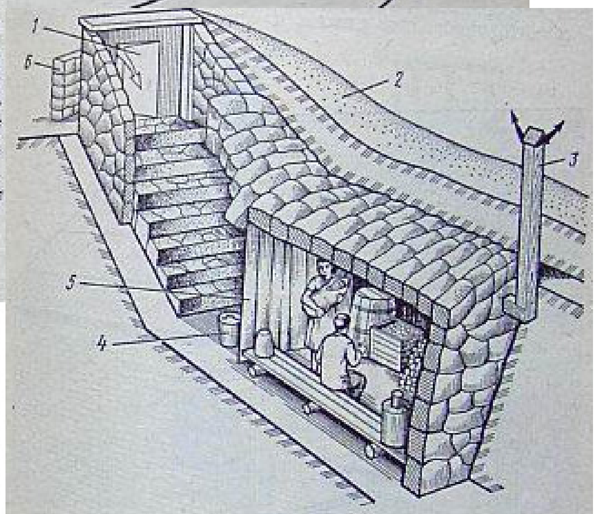


Рис. 25

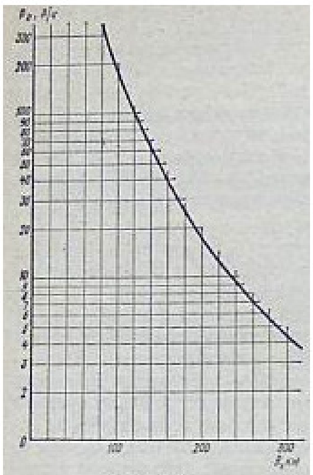


Рис. П.2

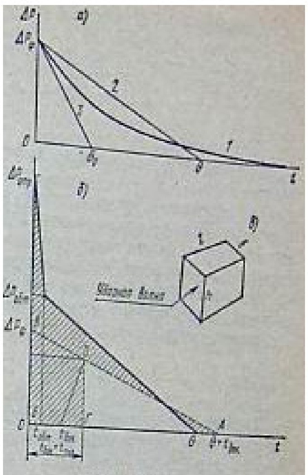


Рис. П.3

$$J = \frac{\Delta P_{max}\,\theta}{2} = \int_0^{\tau} \Delta P(t)\,dt,$$

имальное избыточное давление;

$$\Delta P(t) = \Delta P_{max}\left(1 - \frac{t}{\tau}\right) e^{-\frac{t}{\tau}}.$$

Publishing House for Higher Education (Vysshaya Shkola) Atamanyuk V.G. Civil defense. M., 1987

Civil Defense (Grazhdanskaya Oborona) Moscow 1969 (ORNL-tr-2306)

Civil Defense (Grazhdanskaya Oborona) / Publishing House for Higher Education (Vysshaya Shkola) / Second Edition, Moscow (1970), 500,000 copies [Paperback]

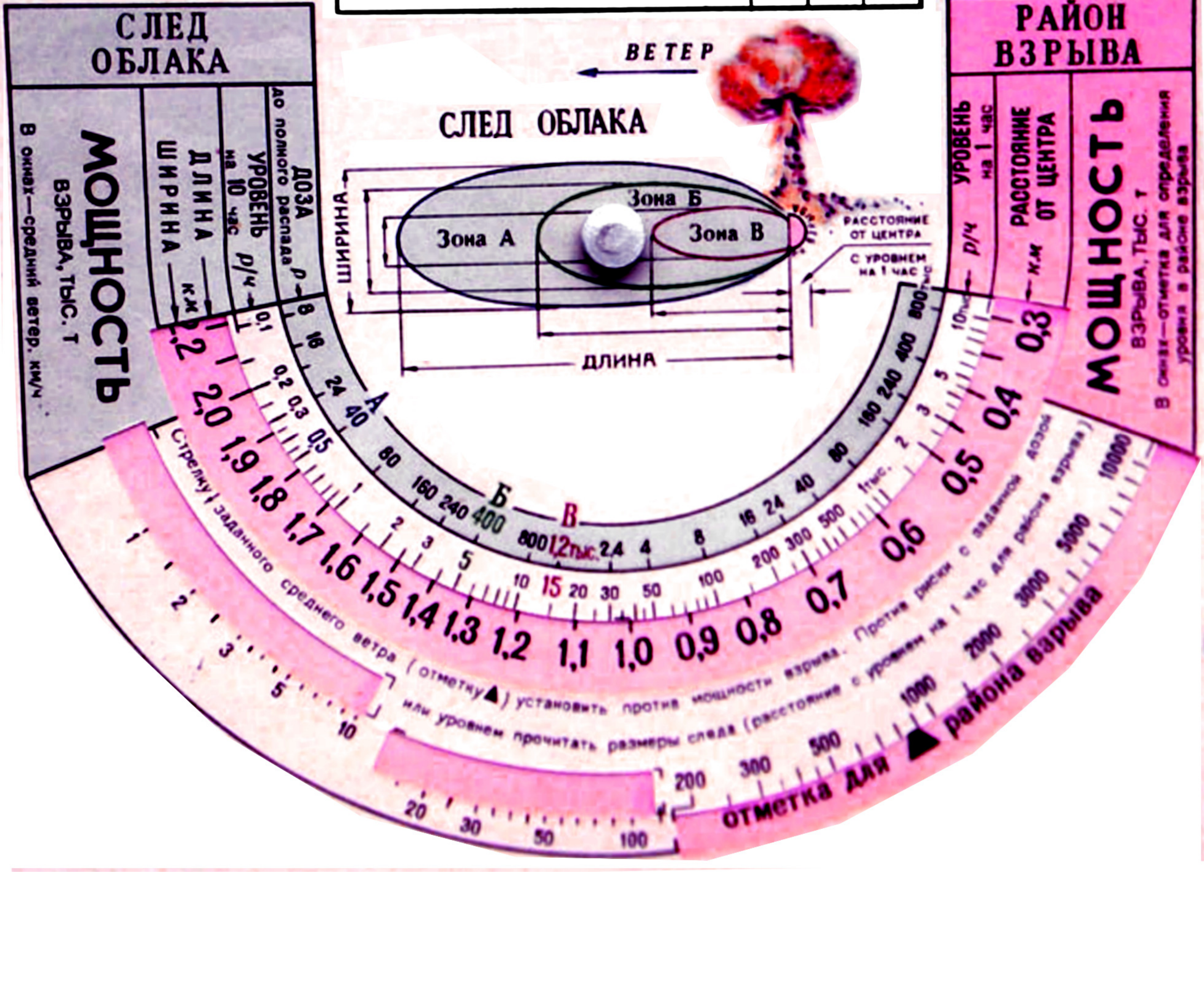
P. T.; Shlyakhov, I. A. and Alabin, N. I.; Oak Ridge National Laboratory Egorov (Author)

ЛИНЕИКА РЛ

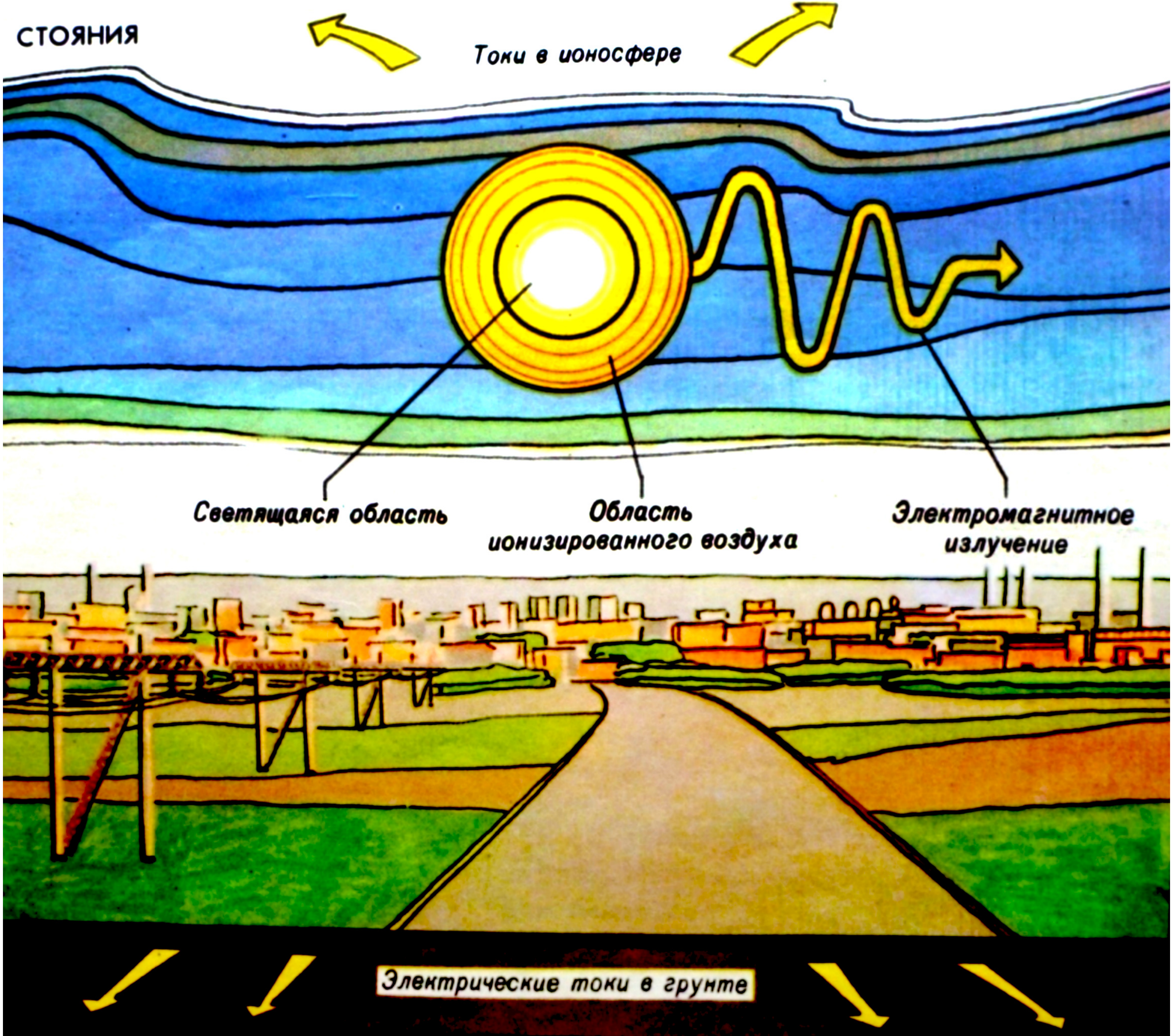
ДЛЯ ОЦЕНКИ РАДИАЦИОННОЙ ОБСТАНОВКИ ПРИ НАЗЕМНЫХ ВЗРЫВАХ

ТАБЛ I ХАРАКТЕРИСТИКИ ЗОН ЗАРАЖЕНИЯ ПО СЛЕДУ ОБЛАКА (НА ВНЕШНИХ ГРАНИЦАХ)

ПОКАЗАТЕЛИ	ЗОНЫ		
	А	Б	В
ДОЗЫ ДО ПОЛНОГО РАСПАДА, р	40	400	1200
СРЕДНИЕ УРОВНИ РАДИАЦИИ, р/ч НА 10 ЧАСОВ ПОСЛЕ ВЗРЫВА	0,5	5	15



СТОЯНИЯ



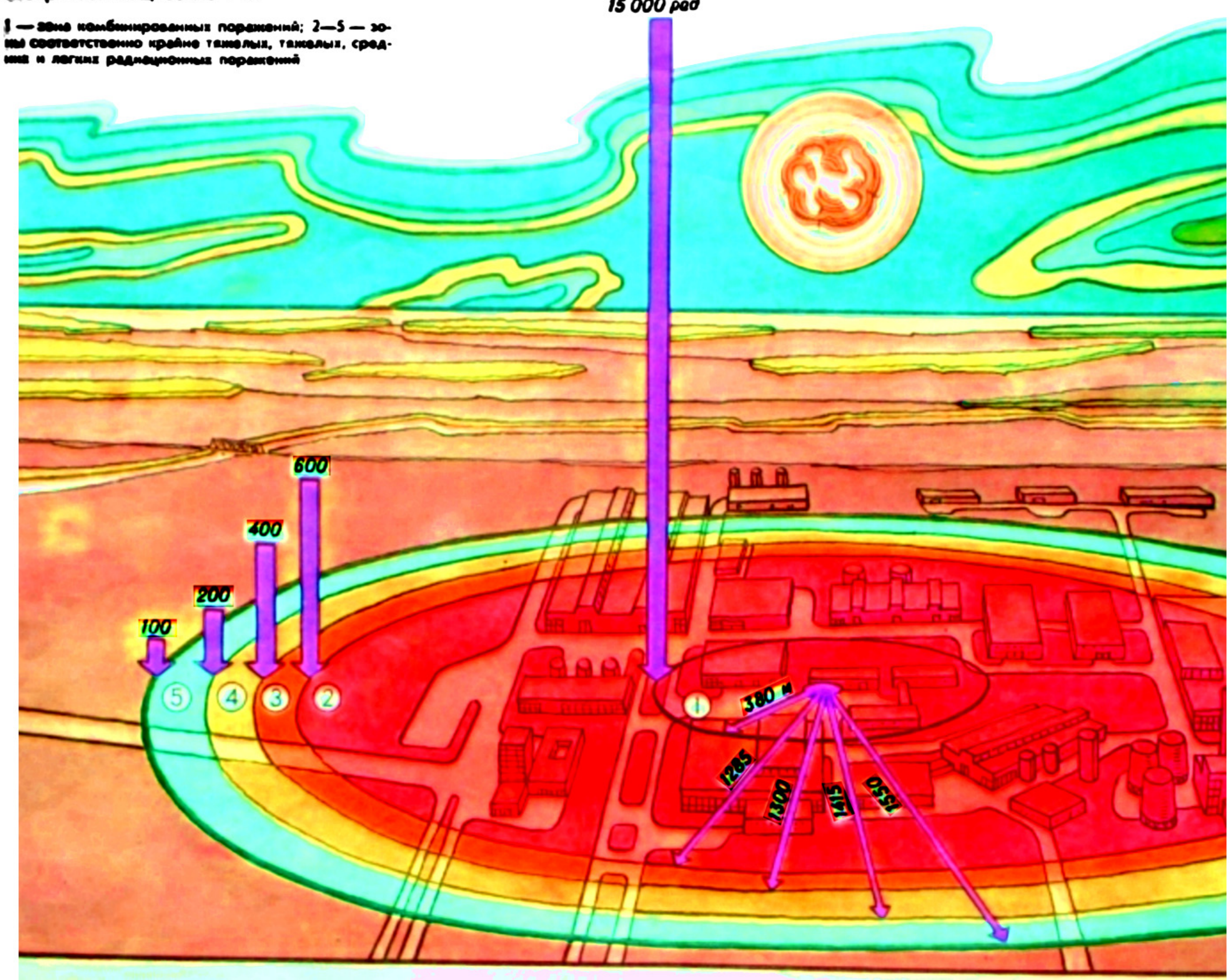
Токи в ионосфере
Светящаяся область
Область ионизированного воздуха
Электромагнитное излучение
Электрические токи в грунте

НЕЙТРОННОЕ ОРУЖИЕ И ОСОБЕННОСТИ ЗАЩИТЫ ОТ НЕГО

НЕЙТРОННОЕ ОРУЖИЕ — ЭТО НЕЙТРОННЫЕ БОЕПРИПАСЫ И СРЕДСТВА ДОСТАВКИ ИХ К ЦЕЛИ. **НЕЙТРОННЫЙ БОЕПРИПАС** — ТЕРМОЯДЕРНЫЙ ЗАРЯД СВЕРХМАЛОЙ МОЩНОСТИ (0,5—2,0 кт), ДЕЙСТВИЕ ЕГО ОСНОВАНО НА РЕАКЦИИ СИНТЕЗА НУКЛИДОВ ВОДОРОДА — ДЕЙТЕРИЯ И ТРИТИЯ

Очаг поражения при взрыве нейтронного боеприпаса мощностью 1 кт

1 — зона комбинированных поражений; 2—5 — зоны соответственно крайне тяжелых, тяжелых, средних и легких радиационных поражений



РАСПРЕДЕЛЕНИЕ ЭНЕРГИИ ВЗРЫВА НЕЙТРОННОГО И ЯДЕРНОГО БОЕПРИПАСА

Поражающий фактор	Энергия боеприпаса, %	
	нейтронного	ядерного
Ударная волна	40	50
Световое излучение	30	35
Проникающая радиация	25	5
Радиоактивное заражение	5	10

ЗАЩИТНЫЕ СВОЙСТВА МАТЕРИАЛОВ

Экспозиционную дозу радиации ослабляют вдвое материалы толщиной

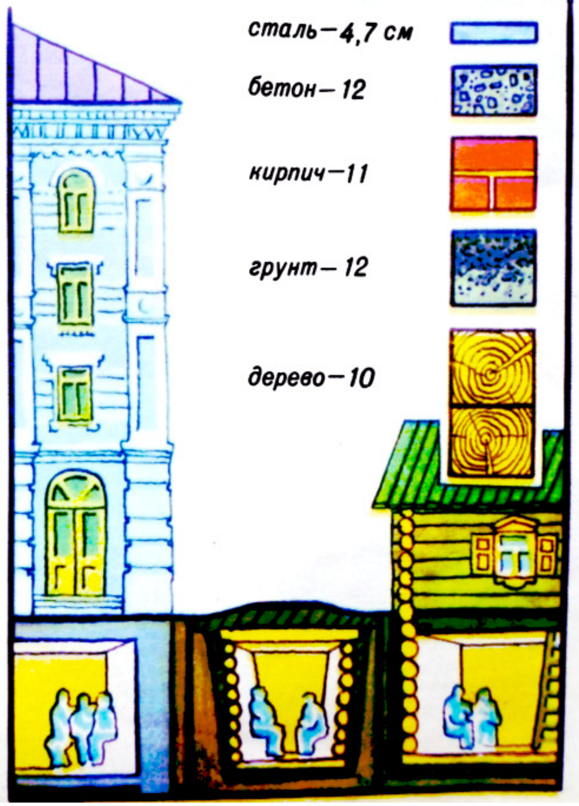
сталь — 4,7 см

бетон — 12

кирпич — 11

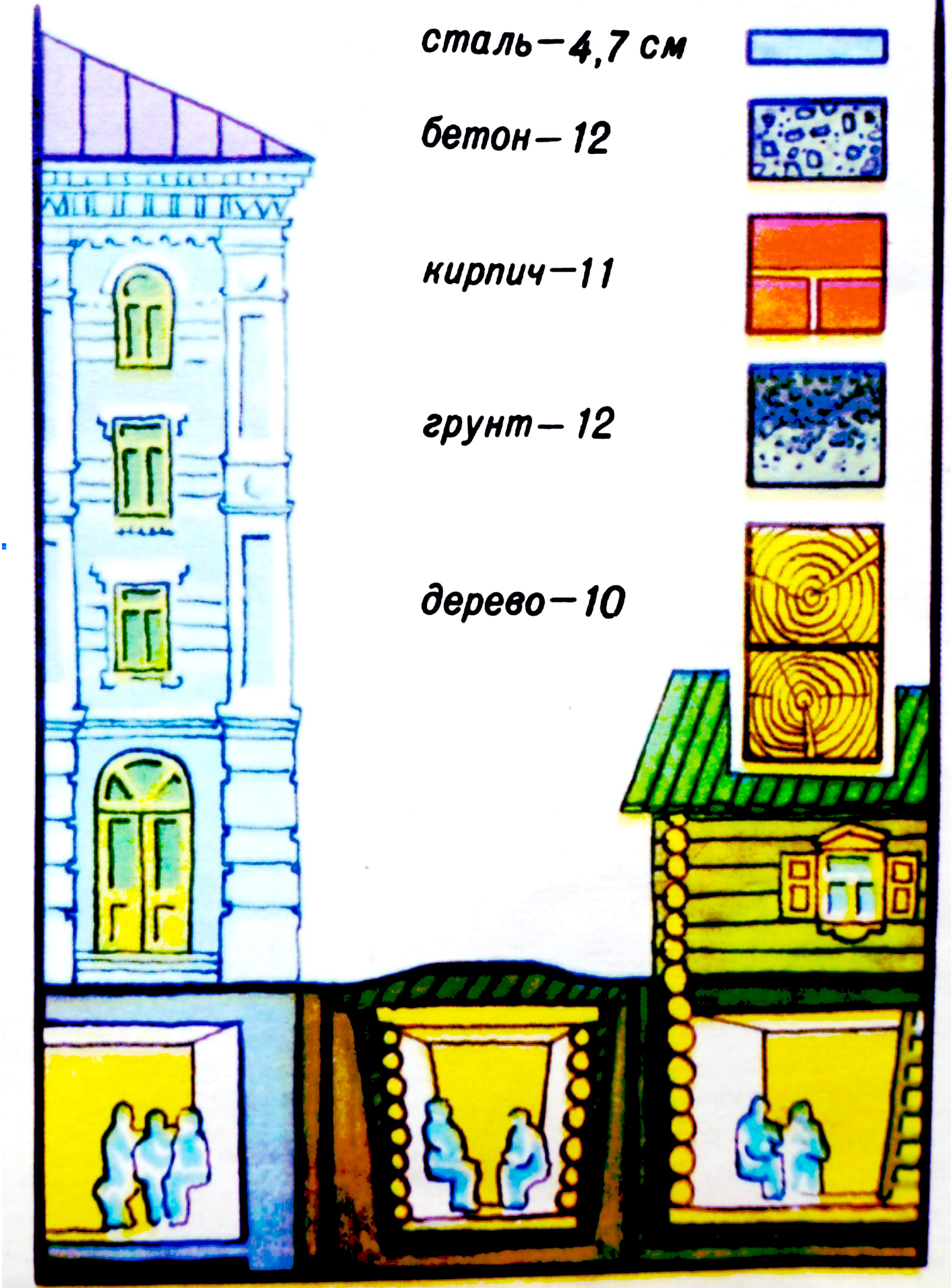
грунт — 12

дерево — 10



ЗАЩИТНЫЕ СВОЙСТВА МАТЕРИАЛОВ

Экспозиционную дозу радиации ослабляют вдвое материалы толщиной



ORNL-4905
UC-41 — Health and Safety

HEALTH PHYSICS DIVISION
Civil Defense Research Project

BLAST TESTS OF EXPEDIENT SHELTERS

by

Cresson H. Kearny and Conrad V. Chester

POR No. 6749

MIDDLE NORTH SERIES

MIXED COMPANY EVENT

FINAL PROJECT OFFICERS REPORT - LN316

JANUARY 1974

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
Operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

BLAST TESTS OF EXPEDIENT SHELTERS

Cresson H. Kearny and Conrad V. Chester

ABSTRACT

Oak Ridge National Laboratory field tests of expedient shelters during the past three years had resulted in the selection and development of six types of expedient shelters. These were demonstrated by construction exercises to be the most practical for average rural and small-town Americans to build in the principal environmental regions of the United States. Each type of shelter is designed to be built within 48 hours by average family groups of such Americans, using only widely available materials such as trees, to provide all members with high-protection-factor shelter. To evaluate the blast protection afforded by these six types of expedient shelters, they were blast tested as a part of Defense Nuclear Agency's Mixed Company Event, in the blast area of a 500-ton TNT detonation--equivalent in air blast effects to a 1.0–1.8 kiloton nuclear detonation.

A total of twelve shelters, representing six expedient types, were subjected to blast effects at surface overpressures ranging from 29 to 3 pounds per square inch (psi). All except the two Door-Covered Trench Shelters were tested as closed shelters. Only one shelter was damaged: the Door-Covered Trench Shelter that was tested as an open shelter at 5 psi.

The six types of shelters, tested at the following measured surface overpressures, were: (1) Two Small-Pole Shelters, at 29 psi; (2) Three Wire-Catenary-Roofed Shelters, at 29 psi and 13 psi; (3) One aboveground A-Frame Pole Shelter, at 17 psi; (4) One Shored-Trench Stoop-In Shelter, at 13 psi; (5) Two Log-Covered Trench Shelters, at 13 psi; (6) Two Door-Covered Trench Shelters, at 5 psi and 3 psi. Earth arching increased the strength of the shelters that had an adequate depth of earth cover relative to the roof span.

1. INTRODUCTION

1.1 THE INCREASING NEED FOR EXPEDIENT SHELTERS AFFORDING IMPROVED BLAST PROTECTION

The United States and most of the other nations with democratic governments have made only weak or token civil defense preparations to enable their civilians or their military personnel to survive a nuclear attack, and thus to lessen the risks of nuclear blackmail or attack. Yet the numbers of nuclear warheads that may possibly strike the United States and her probable allies continue to increase, as do the numbers of Americans and other democratic peoples likely to be within blast areas if nuclear war befalls their countries. Furthermore, existing structures within the probable target areas of these countries would provide much less effective blast protection than would well designed, thoroughly tested expedient shelters of types that a large fraction of civilian populations and most military personnel could build for themselves in 48 hours or less*--provided they were given the necessary leadership and building instructions during an escalating crisis.

National leaders are likely to have at least 48 hours' warning before the outbreak of nuclear war, since the steadily improving Soviet civil defense preparations** are based on the planned evacuation and dispersal of urban Russians during an escalating crisis. Soviet authorities estimate this evacuation and dispersal would reduce Russian fatalities in a nuclear war to a smaller number than the USSR suffered in World War II.** In the foreseeable future, no nation appears at all likely to launch an "out-of-the-blue" nuclear attack.

---

*See "Hasty Shelter Construction Studies," (U), by C. H. Kearny: Chapter 21 of Annual Progress Report, Civil Defense Research Project, March 1970-March 1971, ORNL-4679. (Such "hasty shelters" are now termed "expedient shelters.")

**See the ORNL translations of the most authoritative Soviet civil defense handbooks: Civil Defense, (Moscow, 1969), ORNL-tr-2306, (U), 1972, and Civil Defense, (Moscow, 1970), ORNL-tr-2656, (U), 1973.

ORNL-4888
UC-2 — General, Miscellaneous, and
Progress Reports (Nuclear)

Contract No. W-7405-eng-26

HEALTH PHYSICS DIVISION
Emergency Technology Section

STRATEGIC CONSIDERATIONS IN PLANNING A COUNTEREVACUATION

C. V. Chester
G. A. Cristy
C. M. Haaland

DECEMBER 1975

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

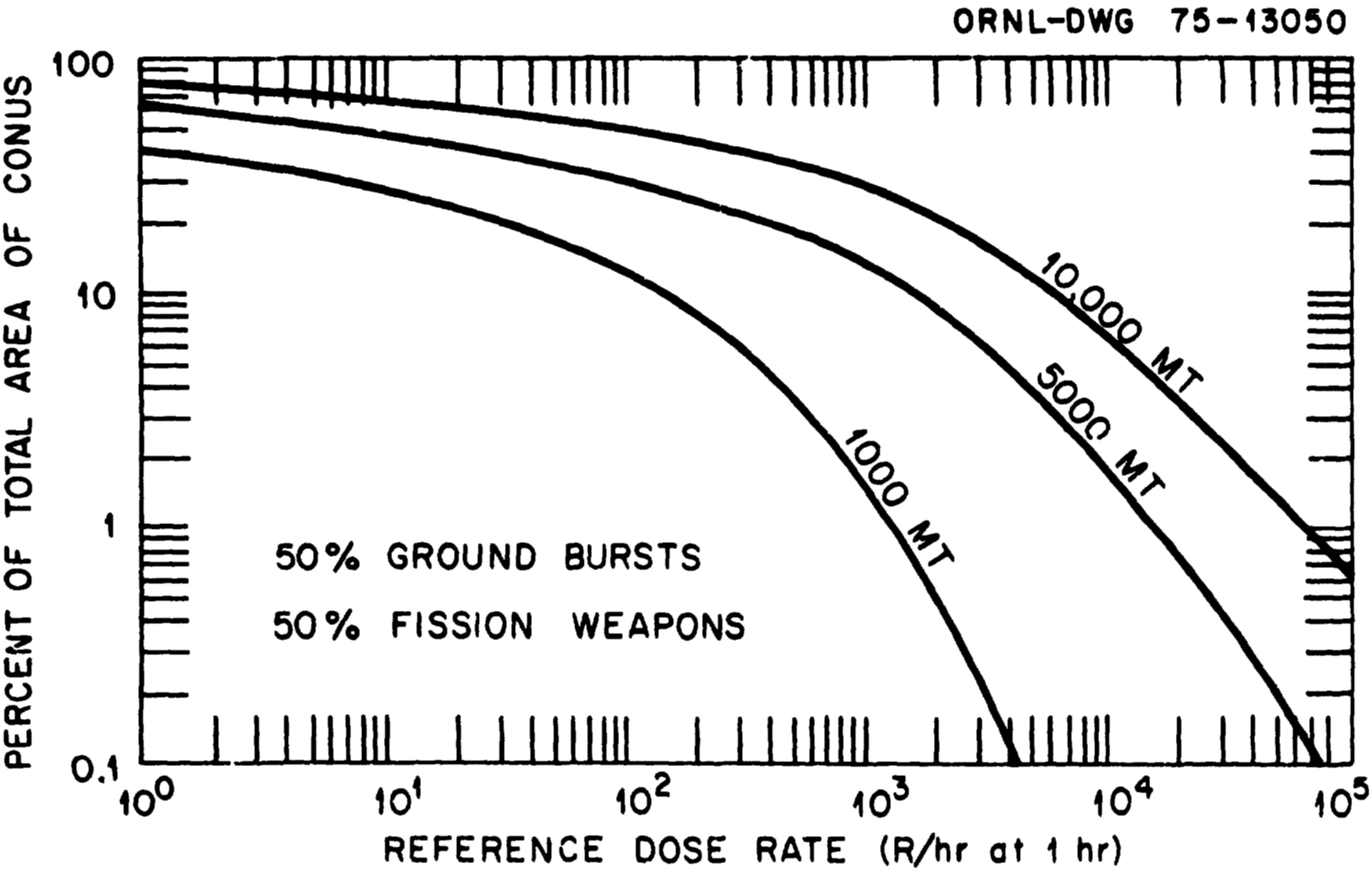


TABLE 2.1. *PROTECTION AVAILABLE FROM EXPEDIENT SHELTER*

Shelter Type	Applicable Site	Fallout* Protection Factor	Blast Resistance (psi)	Construction** Time (hr)
Door-Covered Trench	Stable Soil	200+	5-6	12
Log-Covered Trench	Stable Soil	200+	15-?	36
Wire-Catenary	Stable Soil	200+	15-30	36
Small-Pole	Unsaturated, Unstable Soil High Blast Threat	500+	30-80	48
Israeli	Free Running Soil	500+	20-40	36
A-Frame	High Water Table	20+	20-?	48
Basement	Cold Climate Low Water Table	10-20	2-3	6
Improved Basement	Cold Climate Low Water Table	40-200	10-30	24-72 (est.)

*With entrance kept clear of fallout.

**Tested construction times by rural and small town residents using hand tools.

Survival of Food Crops and Livestock in the Event of Nuclear War

Proceedings of a symposium held at
Brookhaven National Laboratory
Upton, Long Island, New York
September 15–18, 1970

Sponsored by
Office of Civil Defense
U. S. Atomic Energy Commission
U. S. Department of Agriculture

Editors

David W. Bensen
Office of Civil Defense
Arnold H. Sparrow
Brookhaven National Laboratory

December 1971

U. S. ATOMIC ENERGY COMMISSION Office of Information Services

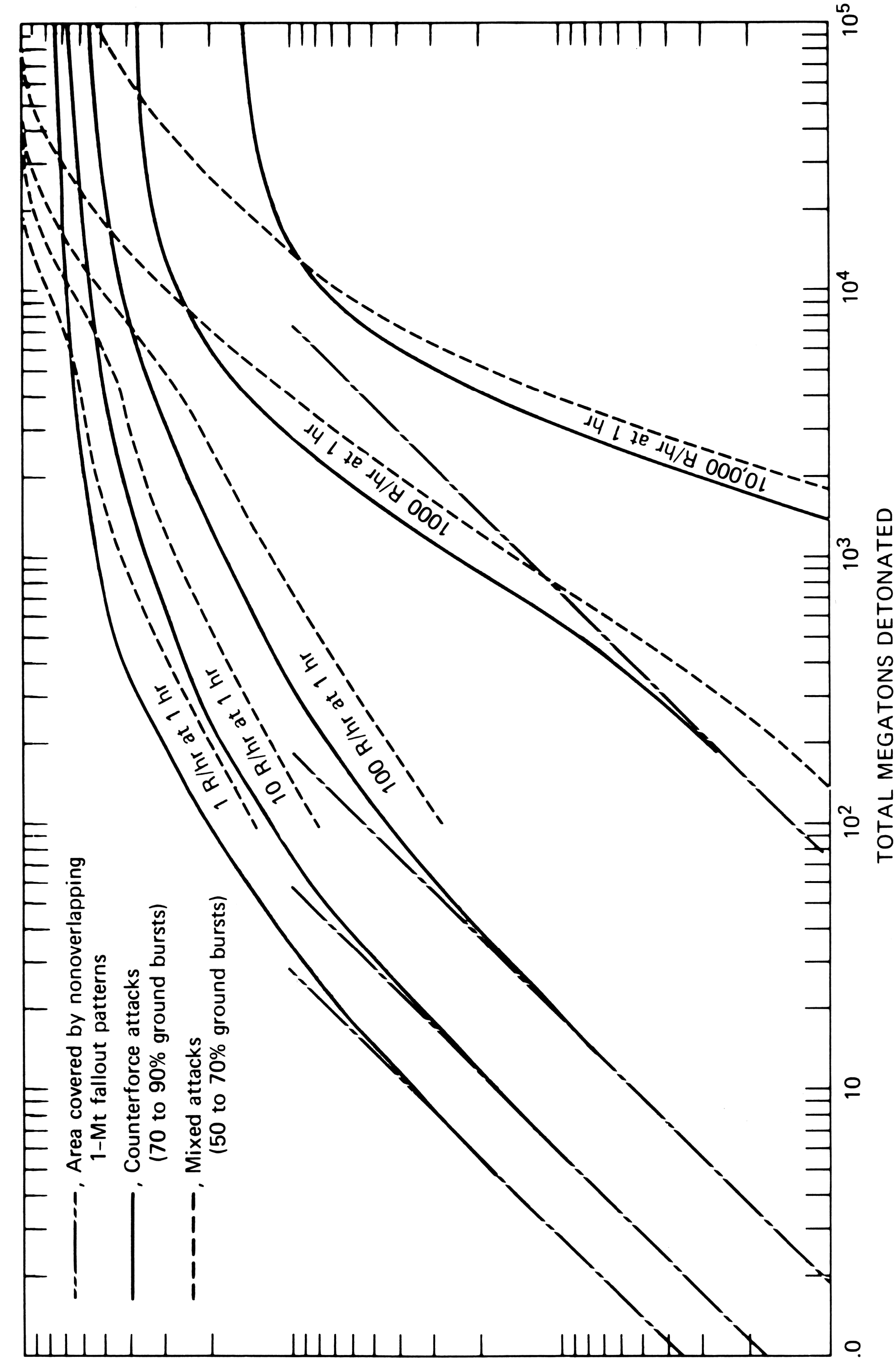


Fig. 1 Percent of area of the continental United States enclosed within selected I_S contours as a function of attack weight (50% fission weapons).

BETA-RADIATION DOSES FROM FALLOUT PARTICLES DEPOSITED ON THE SKIN

S. Z. MIKHAIL
Environmental Science Associates, Burlingame, California

ABSTRACT

Absorbed beta-radiation dose expected from fallout particles deposited on the skin was estimated by use of the Beta Transmission, Degradation, and Dissipation (TDD) model. Comparison of computed doses with the most recent experimental data relative to skin response to beta-energy deposition leads to the conclusion that, even for fallout arrival times as early as 10^3 sec (16.7 min postdetonation), no skin ulceration is expected from single particles 500 μ or less in diameter.

Doses from arrays of fallout particles of different size distributions were computed also for several fallout-mass deposition densities; time intervals required to accumulate doses sufficient to initiate skin lesions were calculated.

In 1954 residents of Rongelap Atoll in the Marshall Islands were exposed to fallout arriving within hours after detonation of the Castle Bravo nuclear device. Several of the atoll's inhabitants suffered severe skin burns. Primarily as a result of this experience, the possibility of "beta burn" from nuclear fallout has been recognized. However, to date, attempts to predict the acute or chronic skin effects that might be expected following exposure to fallout have been limited.

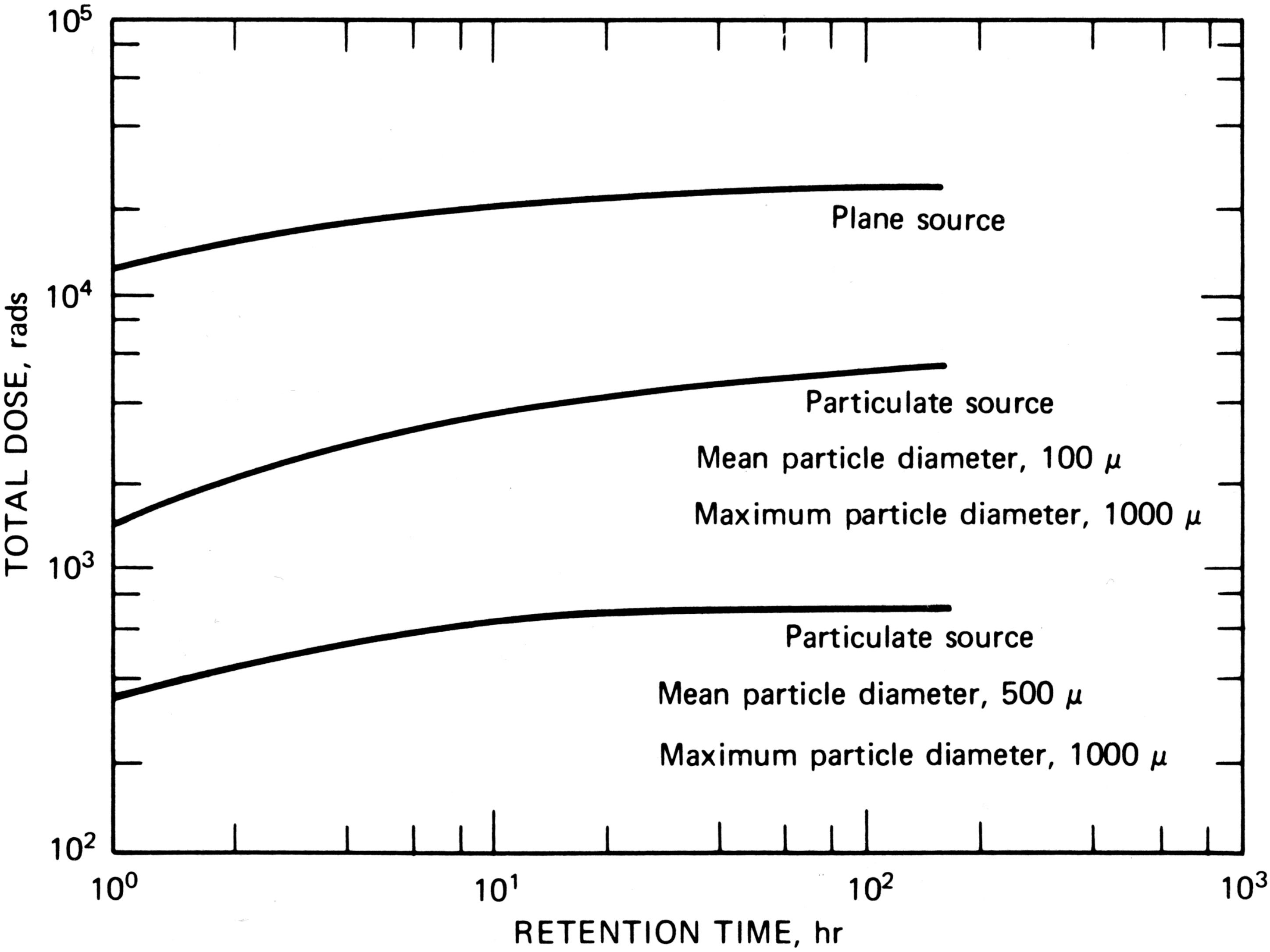


Fig. 6 Comparison between doses computed for a plane source and the corresponding values for a multiparticle source. Tissue depth, 100 μ; delay time, 10^3 sec; deposition density, 100 mg/sq ft; activity, 10^{15} fissions/cc.

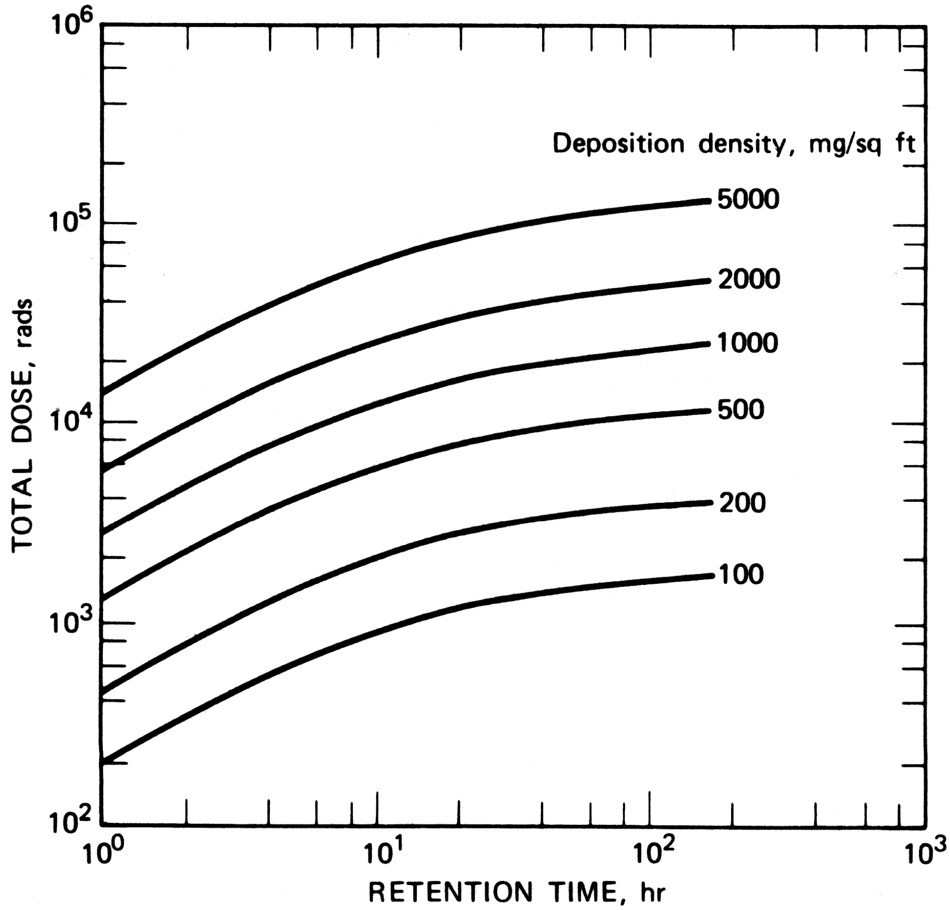


Fig. 13 Dose delivered to the skin by multiparticle fallout of 100-μ mean diameter and 1000-μ maximum diameter at an exposure starting time of 10^4 sec after detonation. Tissue depth, 100 μ.

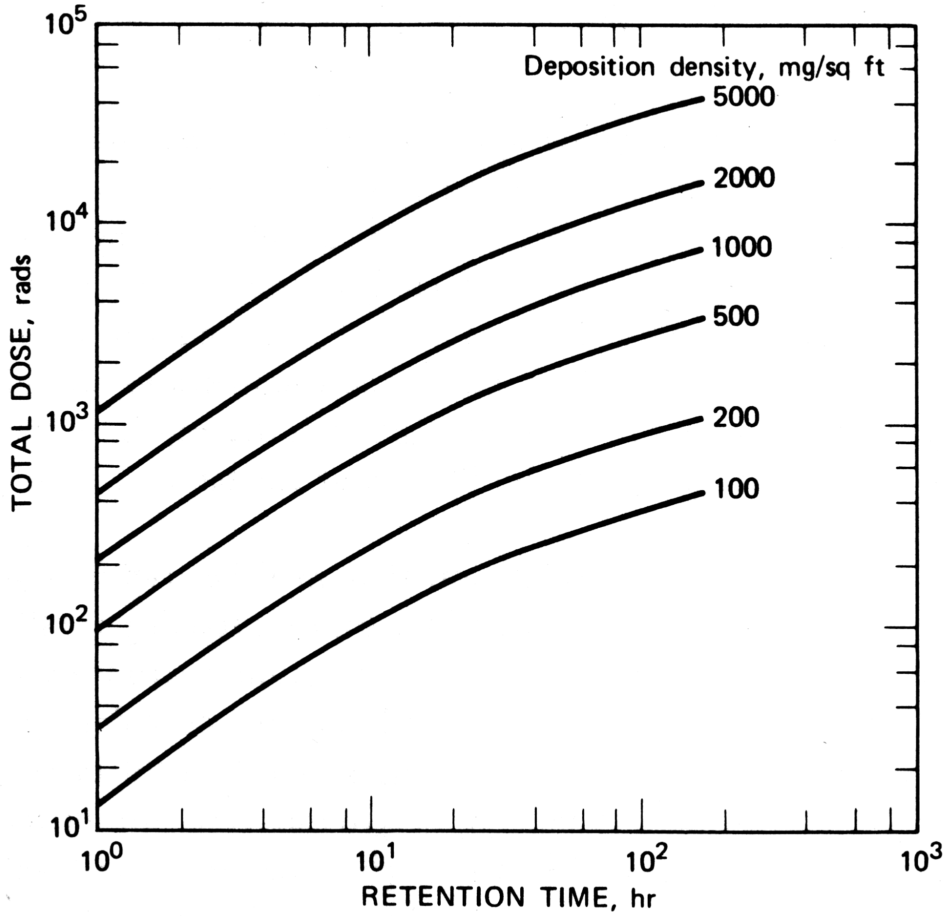
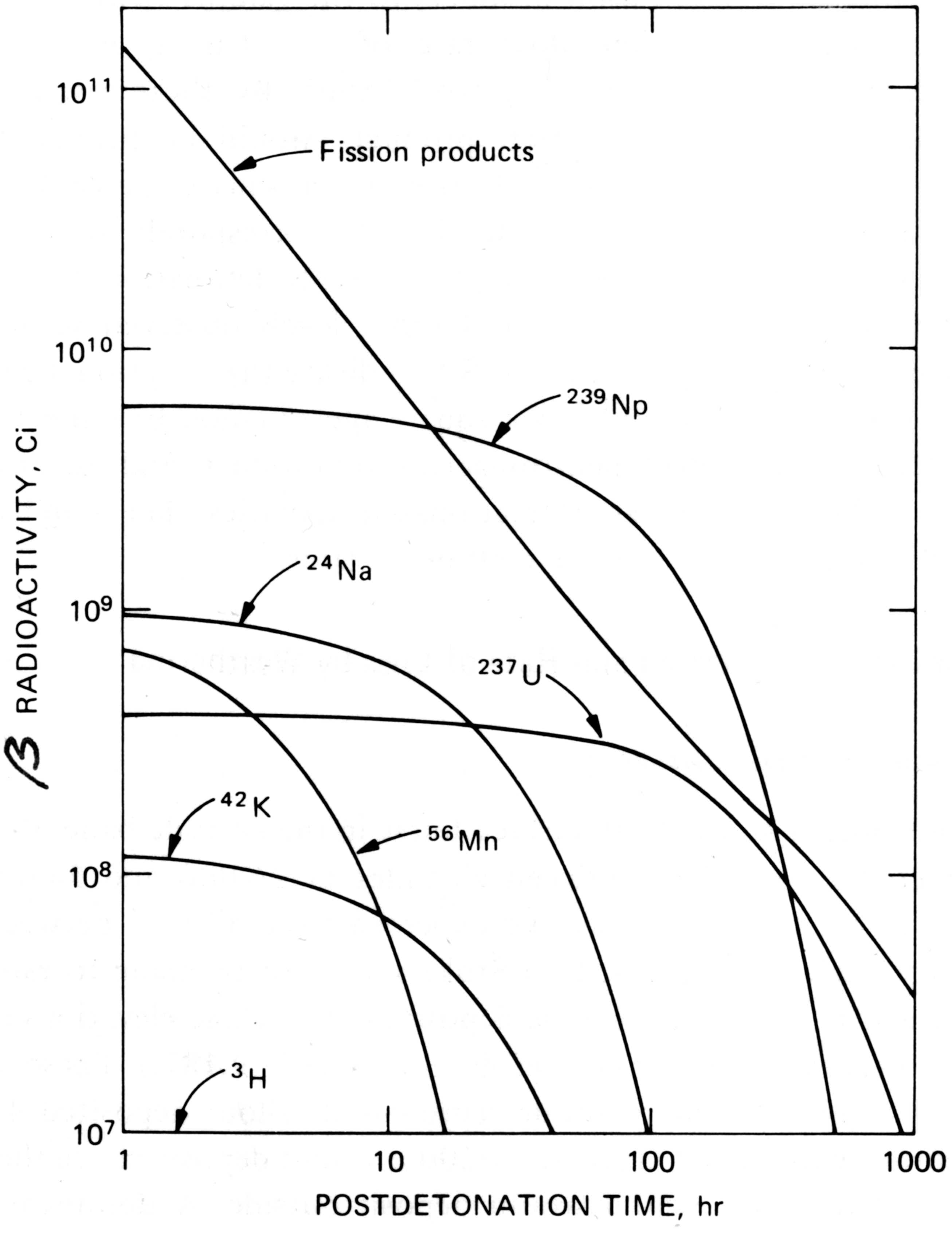


Fig. 14 Dose delivered to the skin by multiparticle fallout of 100-μ mean diameter and 1000-μ maximum diameter at an exposure starting time of 10^5 sec after detonation. Tissue depth, 100 μ.



Radioactivity from 1-Mt explosive with a fission-to-fusion ratio of 1.0.

RADIATION DOSES TO VEGETATION FROM CLOSE-IN FALLOUT AT PROJECT SCHOONER

W. A. RHOADS,* H. L. RAGSDALE,† R. B. PLATT,† and E. M. ROMNEY‡
*EG&G, Inc., Santa Barbara Division, Goleta, California;
†Emory University, Atlanta, Georgia; and ‡University of California,
Laboratory of Nuclear Medicine and Radiation Biology, Los Angeles, California

ABSTRACT

Project Schooner was a nuclear cratering experiment in the Plowshare Program for peaceful application of nuclear explosives. On the basis of information from two earlier experiments, Palanquin and Cabriolet, special dosimeters for measuring both beta and gamma radiation were placed in the open environment and on shrubs in the downwind area where fallout was anticipated. In addition, polyethylene sheets were placed over some shrubs to determine whether the shrubs could thus be protected against radiation damage. The gamma radiation doses for shrubs not covered were found to be essentially the same as the doses measured in the open and away from shrubs, but there was a 15% reduction in dose under the sheets. The beta doses to unsheltered vegetation were, however, reduced by almost 50% compared with doses at 25 cm in the open. This reduction was attributed to self-shielding. Beta doses to the shrubs were reduced still further, to 31% of the 25-cm beta dose in the open, by shielding the shrubs from direct fallout contamination. The estimated LD_{50} for *Artemisia* was 4449 rads, but the reduction in dose by the shelters was nearly sufficient to prevent damage to the shrubs, even though all other *Artemisia* shrubs in the center of the fallout pattern were killed. It was concluded that beta doses must be considered in protecting growing food crops and livestock and that even minimal shelter to prevent direct surface contamination would be of great importance.

Project Schooner was a nuclear experiment in a layered tuffaceous medium, executed as a part of the Plowshare program for development of nuclear excavation. Detonation occurred Dec. 8, 1968, at 0800 (PST) in Area 20 of the Nevada Test Site (NTS). The resultant yield was 31 ± 4 kt (Ref. 1). Other details are published elsewhere. This paper is concerned only with radiation doses and their effects on vegetation along an arc of dosimetry stations approximately 1800 m from ground zero (GZ).

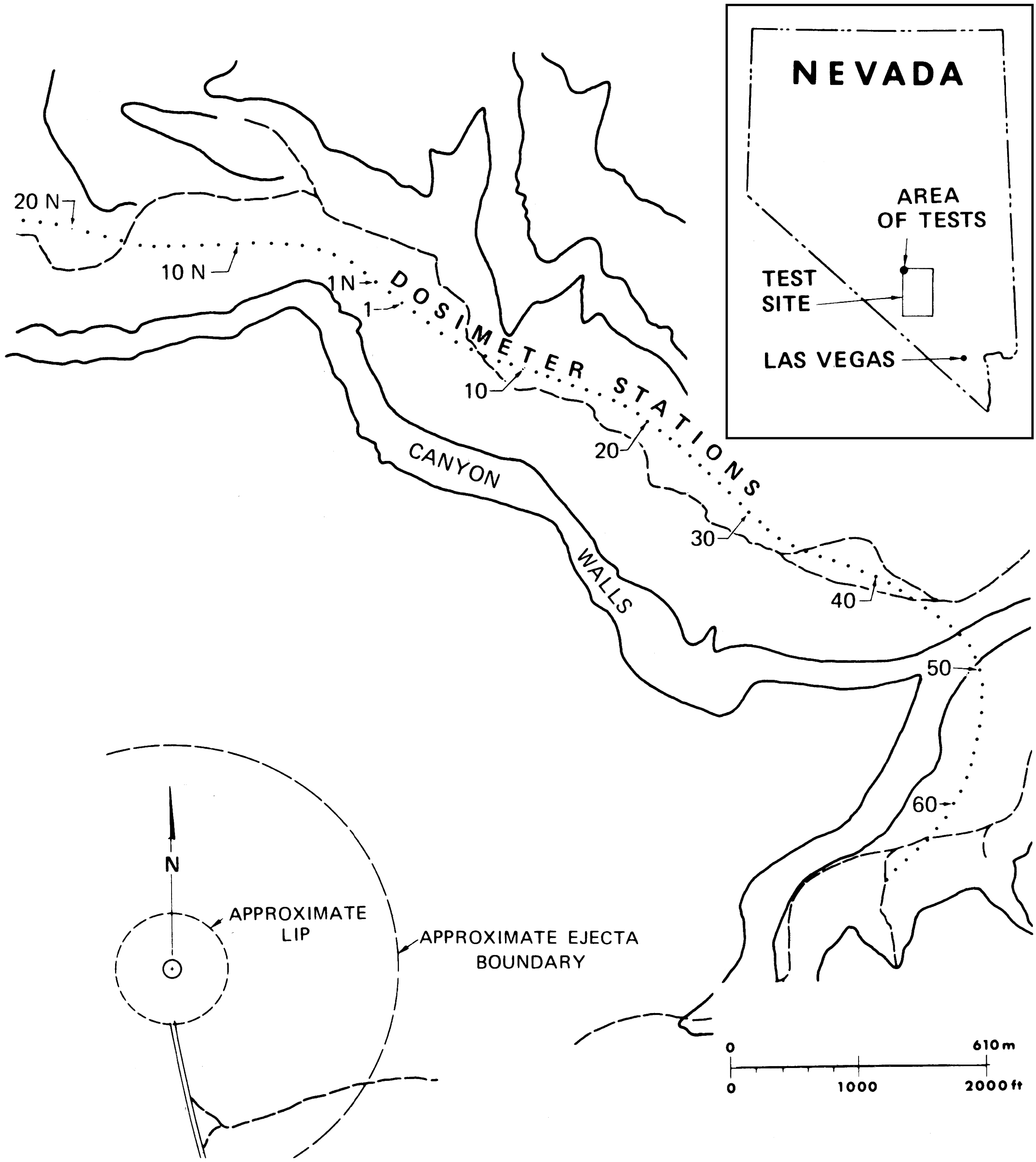


Fig. 1 Schooner crater and the location of the dosimetry stations to the north and east of it.

were not close to other shrubs. Generally, this was not possible among the sheltered shrubs, because of the limited numbers available.

Polyethylene sheets 6 m square and 6 mils thick were spread over as many *Artemisia* shrubs as could be covered conveniently at alternate stations along the arc. Figure 3 shows a protective sheet in place and also provides a general view of the terrain and vegetation.

Fallout from Schooner occurred to the north and northeast of GZ. The dosimeter stations were within the edge of the base surge at the north

Fig. 3 Station 12N, showing a part of a 6-m-square polyethylene sheet in place over *Artemisia* shrubs. The stakes at the right of the covered shrubs mark the locations of dosimeter stations, the dosimeters being held on vertical wires. The point of the cliff in upper center is that shown in Fig. 2 where the trail dead-ends. The vegetation is typical *Artemisia tridentata*.

North of GZ

Artemisia LD_{100} = 5500 rads (ref. 3.)

97 dosimeter stakes N and E of GZ, 1.7—2 km G.R., 35 m apart

Table 1

DOSE ACROSS THE MAIN FALLOUT PATTERN AT 25 CM ABOVE THE SOIL SURFACE AND TO SHRUBS

Station No.	Gamma-ray dose, rads: Dose at 25 cm	Gamma: Shrub Open*	Gamma: Shrub Covered	Gamma: Percent of 25-cm dose Open†	Gamma: Percent of 25-cm dose Covered	Beta-ray dose, rads: Dose at 25 cm	Beta: Shrub Open	Beta: Shrub Covered	Beta: Percent of 25-cm dose Open	Beta: Percent of 25-cm dose Covered	β/γ ratio in open at 25 cm height
12N	280		255		91	2100	1110	630	52	30	7.5 —
10N	380	420	350	+11	92	3420	2160	1590	63	46	9.8 ~~8.14~~
8N	800	810	770	+2	96	7800	3000	2190	39	28	9.75 ~~9.63~~
6N	950	1060	800	+11	84	10650	5250	3000	49	28	11.2 ~~10.0~~
4N	820		710		86	8640	4140	3270	48	38	10.5 —
2N	700	640	610	−9	87	8100	3900	2100	48	26	11.6
0	650	680	470	+5	72	7050	3000	2340	43	33	10.8
2	800	750	660	−6	83	7500	2910	1770	39	24	9.4
4	650	660	480	+2	74	5550	2250	1650	41	30	8.5
6	600	590	600	−2	100	4650	2340	1650	51	36	7.8
8	720	700	600	−3	83	5040	3240	2040	64	40	7
10	800	850	530	+6	66	5400	3600	1560	67	29	6.8
12	620	580	550	−6	89	4450	2190	900	49	20	7.2
14	440		370		84	3480	1620	900	47	26	7.9
16	300	‡	260	‡	87		1650	570			—
18	200	210	200	+5	100	2100	1500	540	71	26	10.5
20	130	120	80	−8	62	1410	990	570	70	39	10.8
			Mean	+0.5	84.5				52.6	31.2	8.52 mean
			Standard deviation	±5.7	±10.8				±10.9	±6.9	

*Only doses differing from the 25-cm doses are shown.
†Percent differences from the 25-cm doses.
‡Dosimeter not recovered.

β self-shielding of shrubs

The decrease to 52.6% in shrub doses is attributed to "self-shielding," which can be envisioned in terms of the masses of vegetation shadowing themselves. Shrubs that were protected from the direct fallout contamination showed even larger reductions in beta doses, however. For the stations shown in Table 1, the covered shrubs received only 31.2% of the beta dose at 25 cm in the open and away from shrubs.

Effects on the Vegetation

The vegetation along the arc of dosimetry stations was examined at biweekly intervals for a period of 6 weeks after the dosimeters were taken from the field; thereafter it was examined at less frequent intervals. No differences between irradiated and nonirradiated vegetation were detectable until late April when an absence of inflorescence development was first noted. As was previously observed at Cabriolet, the first evidence that *Artemisia* had been affected could be seen only by a careful comparison of the nonirradiated with the irradiated shrubs.

Experience has shown that a conspicuous characteristic of *Artemisia* is the occurrence of primordial inflorescences at the beginning of the active growing season, even though *Artemisia* does not come to anthesis until September in the test area. The leaf-color changes that appeared in mid-May and other phenotypic characteristics that foretold complete defoliation and apparent death by September were not evident beforehand.

By the end of June (D + 7 months), all the damage characteristics previously noted at Cabriolet were also apparent at Schooner in the most heavily irradiated parts of the fallout pattern. There were also notable differences, which will be discussed later.

Protected and Unprotected Shrubs

During the months of July and August, two surveys were made of the vegetation along the arc of the dosimeter stations. These surveys revealed that all *Artemisia* shrubs at Stations 4N, 6N, and 7N were killed, with the exception of those shrubs which had been covered with the plastic sheets. There was no damage to covered shrubs except at Station 6N, where four of the six shrubs covered had no damage and two had a small amount of defoliation. At all stations, 8N to 4 inclusively, around the arc, half or more of the uncovered *Artemisia* shrubs were 50 to 100% defoliated. Lesser damage was observed over many other stations.

A 9-month LD_{50} was derived from the August survey. The survey included all *Artemisia* shrubs within a 5-m radius of each dosimeter-support post. Eleven stations from 12N eastward to Station 13 were surveyed; only those stations at which either all or none of the *Artemisia* had been killed were excluded. The shrubs were grouped into two categories: (1) yellow brown to dark gray and

dead or (2) gray green and living. Plants on the end of the radii with more than half their diameter beyond the 5-m limit were omitted. Those with more than half their diameter within the radii were counted. These counts were then used to determine the LD_{50} by probit analysis. Data were determined from all stations even though half the stations did not have shrub doses determined by dosimeters on the shrubs. As shown in Fig. 7, the LD_{50} was 7760 rads. When

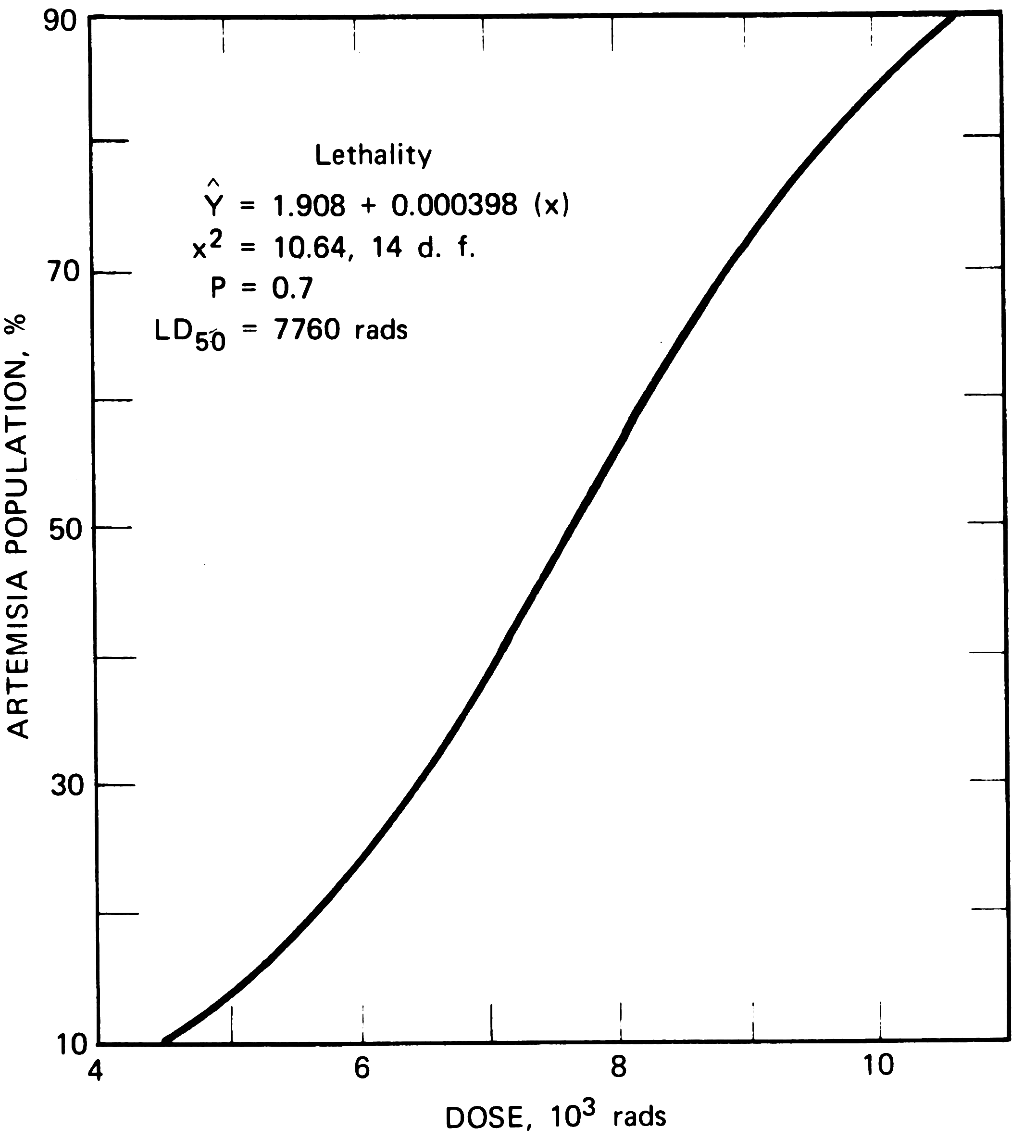


Fig. 7 The LD_{50} for *Artemisia* as of August 1969, 8 to 9 months postevent. The dose, reduced for the self-shielding factor, is 4449 rads.

the beta dose is corrected by the factor 0.526 from Table 1, the dose becomes 4449 rads if, from Fig. 6, the beta-to-gamma ratio is assumed to be 10. It was not possible to derive an LD_{50} with equal precision at Cabriolet, but an LD_{100} for Cabriolet is nearly identical to the LD_{100} for Schooner when the value for Schooner from the 25-cm dose is reduced by the self-shielding factor. Both values are 5500 rads.

SURVIVAL AND YIELD OF CROP PLANTS FOLLOWING BETA IRRADIATION

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ABSTRACT

Field experiments were carried out to investigate the effect of beta radiation on the growth of wheat, lettuce, and corn. The beta-radiation exposure was accomplished by fusing ^{90}Y onto 88- to 175-μ silica sand, and applying the sand to the crops with a remote-control applicator. Treatment levels on the wheat and lettuce crops ranged up to 59.4 mCi of ^{90}Y per square foot. In the corn experiment the highest level was 71.3 mCi of ^{90}Y per square foot. Wheat grain production was severely reduced when 6.6 mCi/sq ft of ^{90}Y was applied. This corresponds to approximately 2700 rads at the surface of the plant near the apical meristem. Lettuce yields were reduced significantly only at the highest treatment level, 59.4 mCi/sq ft, which corresponds to 9300 rads at the plant surface near the apical meristem. Some abnormalities could be seen on the lettuce at the 6.6 mCi/sq ft treatment level. Corn yield was not reduced and plant appearance was not changed in any of the treatments. The apical meristem of the corn plant was protected by about 1 cm of tissue, and it hence received very little ionizing radiation.

In the event of nuclear war, standing crops would be exposed to ionizing radiation from fallout containing both beta and gamma radiation in generally similar amounts. The study reported here is an investigation of the possible effects from the beta component.

Extensive literature exists on the effects of gamma radiation on plants in contrast to the very limited information available concerning the effects of beta exposure to plants.

It is widely accepted that the relative biological effectiveness (RBE) of beta to gamma doses is essentially unity[1] in the moderate and high beta energies found in fallout resulting from a nuclear detonation. This means that, when given ergs of energy are transferred to a fixed amount of tissue, deleterious effects will be the same whether the ionizing radiation is beta or gamma. In spite of this consideration, few predictions can be made of beta damage from gamma data, because of geometrical effects. The gamma exposure tends to be uniform

EFFECTS OF EXPOSURE TIME AND RATE ON THE SURVIVAL AND YIELD OF LETTUCE, BARLEY, AND WHEAT

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ABSTRACT

Experiments were conducted to compare the effects of ^{137}Cs gamma radiation given as either 1-, 4-, 8-, or 16-hr treatments at constant rates (CR) with 36-hr fallout-decay-simulation (FDS) or with buildup (Bu) and fallout-decay-simulation (Bu + FDS) treatments with variable exposure rates. Seedlings of lettuce were given Bu + FDS, FDS, and 1-, 4-, 8-, and 16-hr CR treatments. Barley and wheat seedlings were given FDS and 8- and 16-hr CR treatments. Following irradiation the lettuce plants were transplanted to the field, barley to the greenhouse, and wheat to a growth chamber. The criteria of effect used were survival and yield. Young barley seedlings were given a total exposure of 1600 R at 32 different rates ranging from 60 to 4800 R/hr. The first leaf of each seedling was measured after 8 days of growth.

For equal total exposures, FDS treatments were more effective than 16-hr CR treatments in reducing survival and yield of all three crops. The ratio of 16-hr CR to FDS at LD_{50} was 1.43 for lettuce, 1.23 for barley, and 1.37 for wheat. For yield the FDS was more effective only at exposures above the LD_{50}. Lettuce survival increased with exposure time between 1 and 16 hr, but this was a linear increase only after 4 hr. Barley seedling height decreased as the exposure rate increased from 60 to about 1000 R/hr. Further increases in exposure rate above 1000 R/hr had no further effect on seedling height. The greater effectiveness of the high exposure rates observed in these experiments substantiates our conclusion that the increased effect of an FDS treatment compared with a 16-hr CR treatment is attributable to the high initial exposure rates of FDS.

Similar results for survival and yield reduction for the 8-hr CR and the FDS treatments were observed. Hence investigators lacking the facilities to simulate fallout decay could use an 8-hr CR treatment to approximate the effects of simulated-fallout-decay treatments.

For equal total exposures of gamma radiation, a treatment simulating fallout decay has been reported[1-3] to be more effective in reducing survival and yield of crop plants than are prolonged constant-exposure-rate treatments. The greater effectiveness of the fallout-decay-simulation (FDS) treatment is thought to be due to the very high exposure rates encountered initially.[1-3] Thus study of the

Table 1

COMPARISON OF THE SURVIVAL END POINTS FOR 1-, 4-, 8-, AND 16-HR CR TREATMENTS FOR LETTUCE

	1-hr CR, kR ± S.D.*	4-hr CR, kR ± S.D.	8-hr CR, kR ± S.D.	16-hr CR, kR ± S.D.
LD_{10}	2.35 ± 0.06	3.03 ± 0.15	4.59 ± 0.11	6.39 ± 0.11
LD_{50}	2.57 ± 0.06	3.47 ± 0.10	5.03 ± 0.07	7.01 ± 0.07
LD_{90}	2.78 ± 0.08	3.90 ± 0.12	5.46 ± 0.13	7.64 ± 0.10

*The abbreviation S.D. is standard deviation.

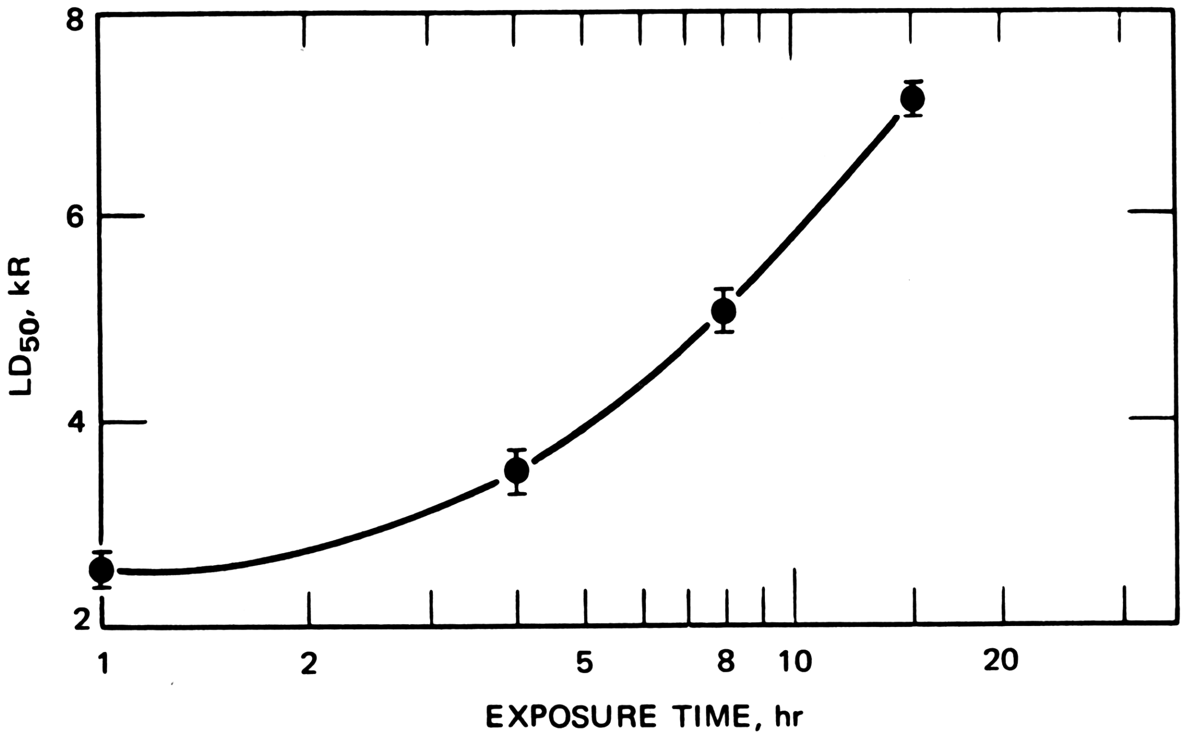

Fig. 4 **LD_{50} vs. log of exposure time for lettuce irradiated for 1, 4, 8, and 16 hr at constant rates. ⊤⊥ indicates ± standard deviation.**

were used, but the results are consistent with those for the other species in showing the FDS treatment to be more effective in reducing survival than the 16-hr CR treatment. The yield data (Fig. 6) resemble the lettuce data (Fig. 3b) in that there is little difference between the FDS and 16-hr CR treatments at the lower exposures, but at exposures of 4 kR or more the CR treatment is clearly less effective in reducing yield. The 16-hr CR values are consistently above the FDS values although they are not always significantly different from them. Representative plants from the surviving exposures of the three treatments are shown in Fig. 7.

The probit plot of survival for wheat against exposure is given in Fig. 8, and again the FDS treatment was more effective in reducing survival than the 16-hr CR treatment. The yield data (Fig. 9) are similar to those for lettuce and barley

Table 2

COMPARISON OF LD_{50} VALUES FOR THE 8-HR CR AND FDS TREATMENTS FOR LETTUCE, BARLEY, AND WHEAT

Crop	Treatment	LD_{50}, kR ± S.D.*	
Lettuce	FDS	4.79 ± 0.05	N.S.†
	8-hr CR	5.03 ± 0.07	
Barley	FDS	1.99 ± 0.08	N.S.
	8-hr CR	1.91 ± 0.04	
Wheat	FDS	3.09 ± 0.71	N.S.
	8-hr CR	3.45 ± 1.12	

*The abbreviation S.D. is standard deviation.

†The abbreviation N.S. means not significant at the 5% level.

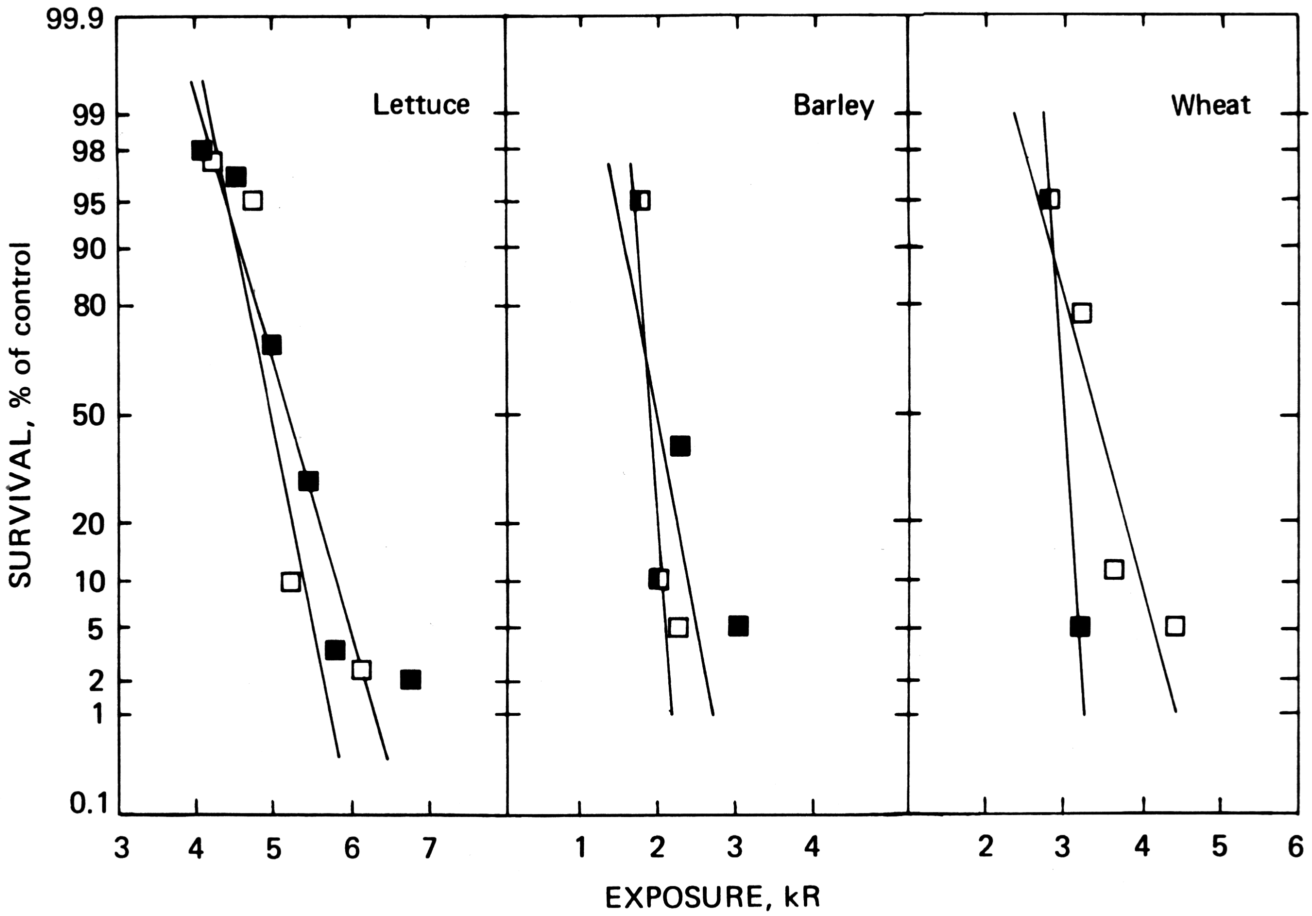

Fig. 11 Comparison of probit plots of survival as percent of control vs. exposure for lettuce, barley, and wheat given 8-hr CR (□) and 36-hr FDS treatments (■).

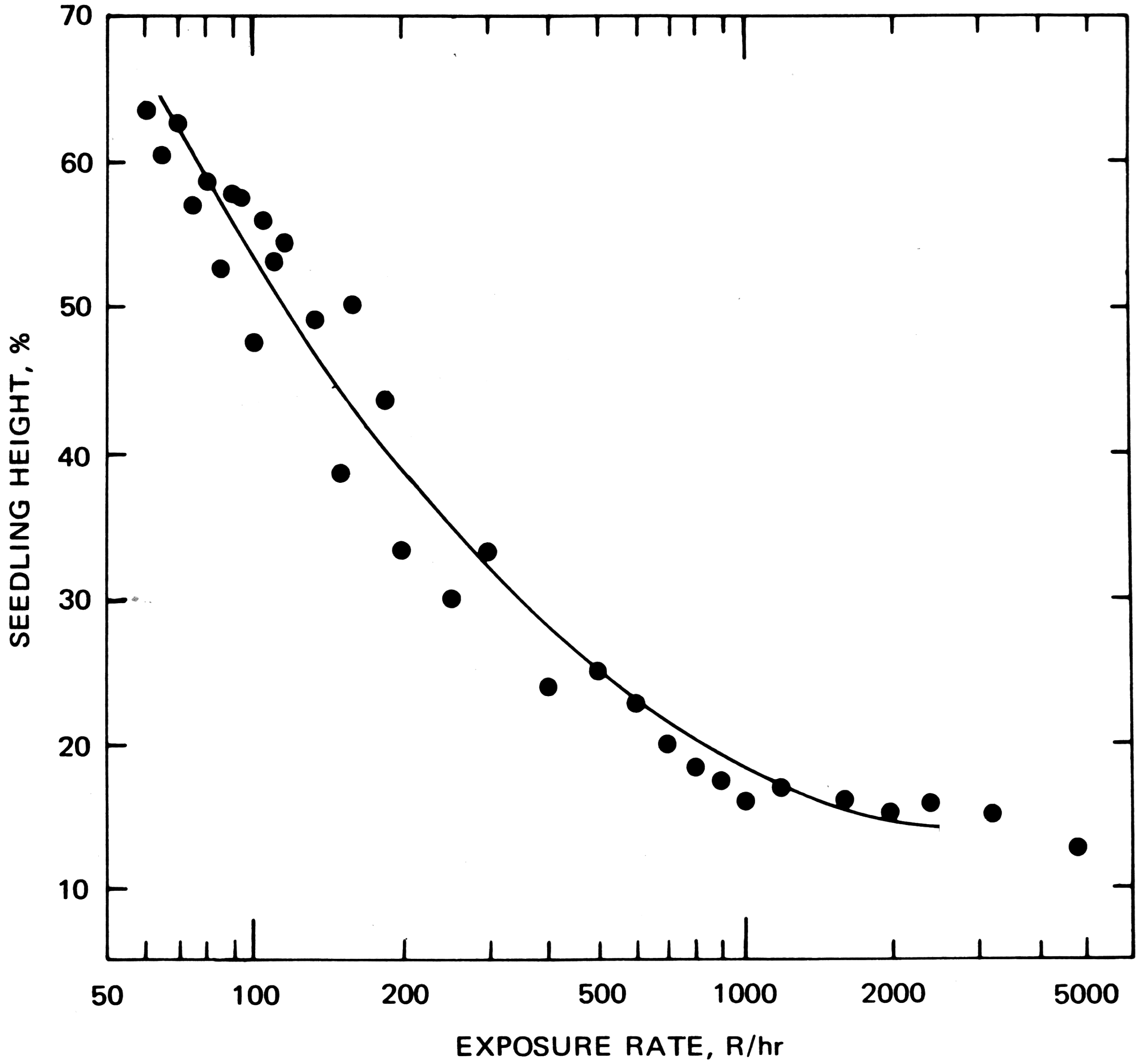

Fig. 15 Seedling height as percent of control vs. log of exposure rate for barley seedlings given a total exposure of 1600 R.

to demonstrate an effect at higher exposure rates since the capacity of the system to respond would be greater under conditions more conducive to expression of the effect.

We have reported both here and previously[1,2] that the FDS treatment is more effective in reducing survival and yield than the 16-hr CR treatment. The ratios of exposures at the LD_{50} for 16-hr CR to FDS are 1.43 for lettuce, 1.23 for barley, and 1.37 for wheat; these ratios agree well with the average of 1.4 for seven other species previously reported. The constant difference between the two treatments which was observed for survival was not observed for yield. At exposures up to the region of the FDS LD_{50}, little difference between the two treatments was observed. Above this exposure the yield for the FDS treatment falls off much more rapidly than the yield for the 16-hr CR treatment, and there is clearly a difference between the two. This difference in effectiveness is due to the very high exposure rates encountered in the early part of the FDS treatment. The average exposure rate in roentgens per hour (weighted for the shield

RADIATION EFFECTS ON FARM ANIMALS: A REVIEW

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ABSTRACT

Hematopoietic death would predominate in food-producing animals exposed to gamma radiation under fallout conditions leaving animal survivors. Gamma-radiation doses of about 900 R would be lethal to 50% of poultry, and about half this level would be lethal for cattle, sheep, and swine. Grazing cattle and sheep would suffer most from combined radiation effects of skin-beta and ingested-beta radioactivity plus the whole-body gamma effects. The $LD_{50/60}$ for combined effects in ruminants is estimated to be at a gamma exposure of around 200 R in an area where the forage retention is 7 to 9%.

Either external parasites or severe heat loss could be a problem in skin irradiated animals. Contrary to early reports, bacterial invasion of irradiated food-producing animals does not appear to be a major problem. Productivity of survivors of gamma radiation alone would not be affected, but, in an area of some lethality, the productivity of surviving grazing livestock would be severely reduced owing to anorexia and diarrhea. Sheltering animals and using stored feed as countermeasures during the first few days of livestock exposure provide much greater protection than shielding alone.

The purpose of this review is to summarize the data available on the effects of ionizing radiation on food-producing animals which would be of value in predicting the effects that could be encountered from radioactive fallout in the event of nuclear war. Most of the data are limited to somatic effects of gamma and beta radiation on survival and productivity of cattle, swine, and sheep. Although much more information is available on radiation effects in small laboratory animals, it is difficult to extrapolate these data to large food-producing animals exposed to a combination of internally and externally applied radiation. Some attention is also given to measures that could be used to reduce radiation exposure of food-producing animals.

Ionizing radiation from radioactive fallout occurs principally as beta particles and gamma rays. The median beta energies are between 0.3 and 0.4 MeV, but the maximum may be up to 5 MeV. Most of the data available on beta

irradiation effects on food-producing animals were obtained by using either ^{90}Y or ^{90}Sr—^{90}Y, which have higher average energies than are characteristic of local fallout. Information on gamma irradiation was obtained principally by exposing large animals to ^{60}Co or ^{137}Cs, which have penetration characteristics similar to gamma fallout radiation.

Limited information is given on neutron exposures, and none is given on alpha radiation since neither of these emissions is expected to be of any consequence in radioactive-fallout effects on food-producing animals.

RADIATION LETHALITY

General

Exposures to gamma radiation at dose rates expected under fallout conditions causing early deaths in about half of the animals are expressed as a dose lethal to 50% in either 30 or 60 days ($LD_{50/30}$ or $LD_{50/60}$). This mortality level varies with dose rate, quality and type of radiation, animal species, and a number of other variables. The upper and lower limits of the distribution of radiation deaths for adult cattle, swine, and burros are shown by the typical sigmoid curves in Fig. 1. The data obtained from ^{60}Co exposure to

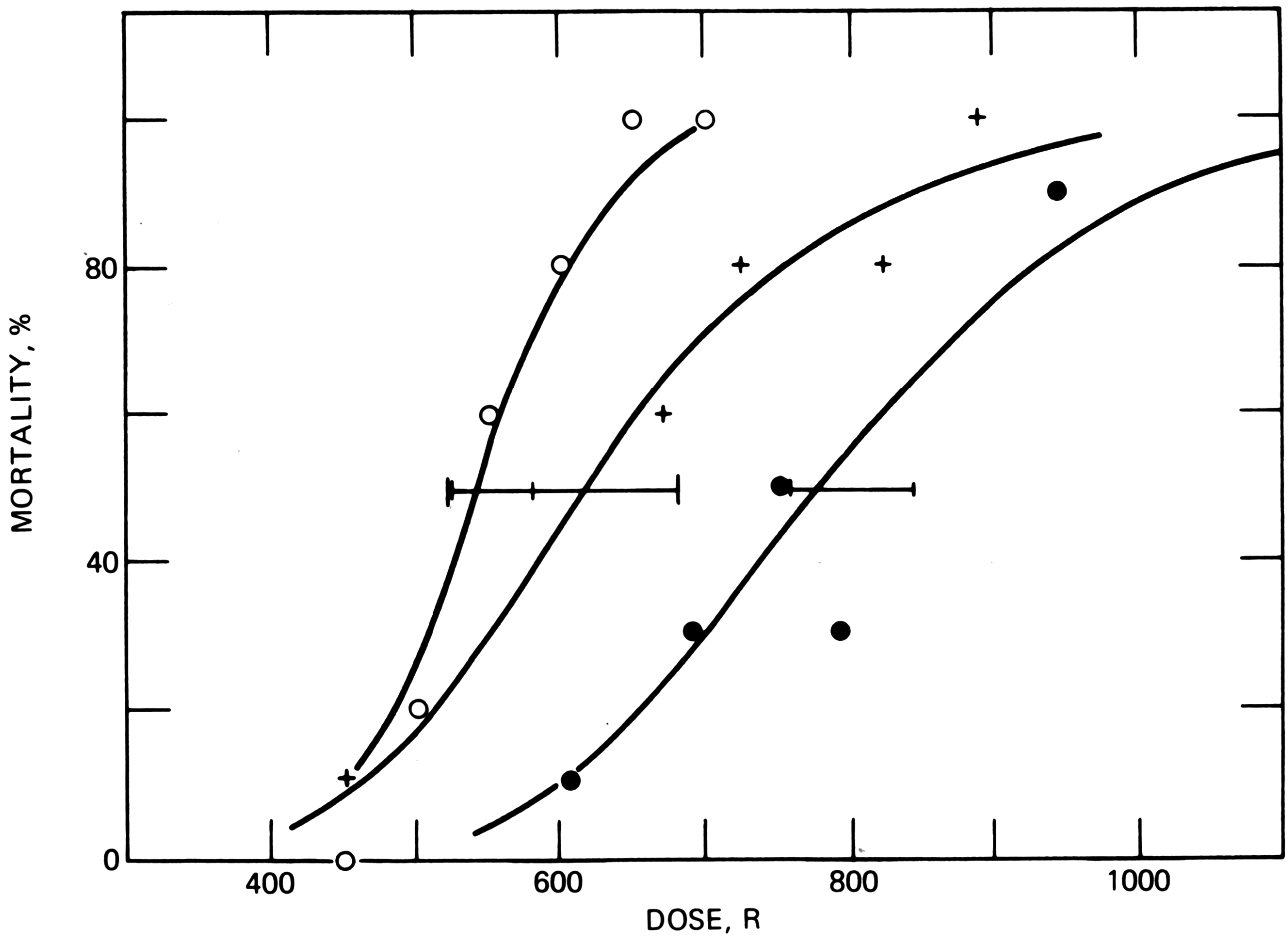

Fig. 1 Mortality of three species exposed to ^{60}Co at a dose rate between 0.5 and 1 R/min. ○, cattle; +, swine; ●, burros; ⊢⊣, 95% confidence interval. (Data from D. G. Brown, UT—AEC Agricultural Research Laboratory.)

THE SIGNIFICANCE OF LONG-LIVED NUCLIDES AFTER A NUCLEAR WAR

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ABSTRACT

The radiation doses from the long-lived nuclides ^{90}Sr and ^{137}Cs, to which the surviving population might be exposed after a nuclear war, are considered using a new evaluation of the transfer of ^{90}Sr into food chains.

As an example, it is estimated that, in an area where the initial deposit of near-in fallout delivered 100 R/hr at 1 hr and there was subsequent worldwide fallout from 5000 Mt of fission, the dose commitment would be about 2 rads to the bone marrow of the population and 1 rad to the whole body. Worldwide fallout would be responsible for the major part of these doses.

In view of the possible magnitude of the doses from long-lived nuclides, the small degree of protection that could be provided against them, and the considerable strain any such attempt would impose on the resources of the community, it seems unrealistic to consider remedial measures against doses of this magnitude. Civil-defense measures should be directed at mitigating the considerably higher doses that short-lived nuclides would cause in the early period.

It is now widely recognized that long-lived fission products would make a negligible contribution to the radiation exposure of the population in heavily contaminated areas shortly after a nuclear attack. The external radiation dose would usually be dominant, and, if simple precautions were taken to avoid the superficial contamination of foodstuffs, the entry of ^{131}I into milk would cause the only important problem of dietary contamination. Thus, for example, infants probably would not receive doses of more than 0.1 rad to bone marrow from ^{90}Sr nor more than 0.01 rad from ^{137}Cs in the weeks after a nuclear attack if they were fed continuously with milk produced in an area where the external dose rate at 1 hr after detonation had been 100 R/hr. Doses to the thyroid from ^{131}I might, however, exceed 200 rads.[1] Considerably higher doses from dietary contamination were expected until it became evident that the

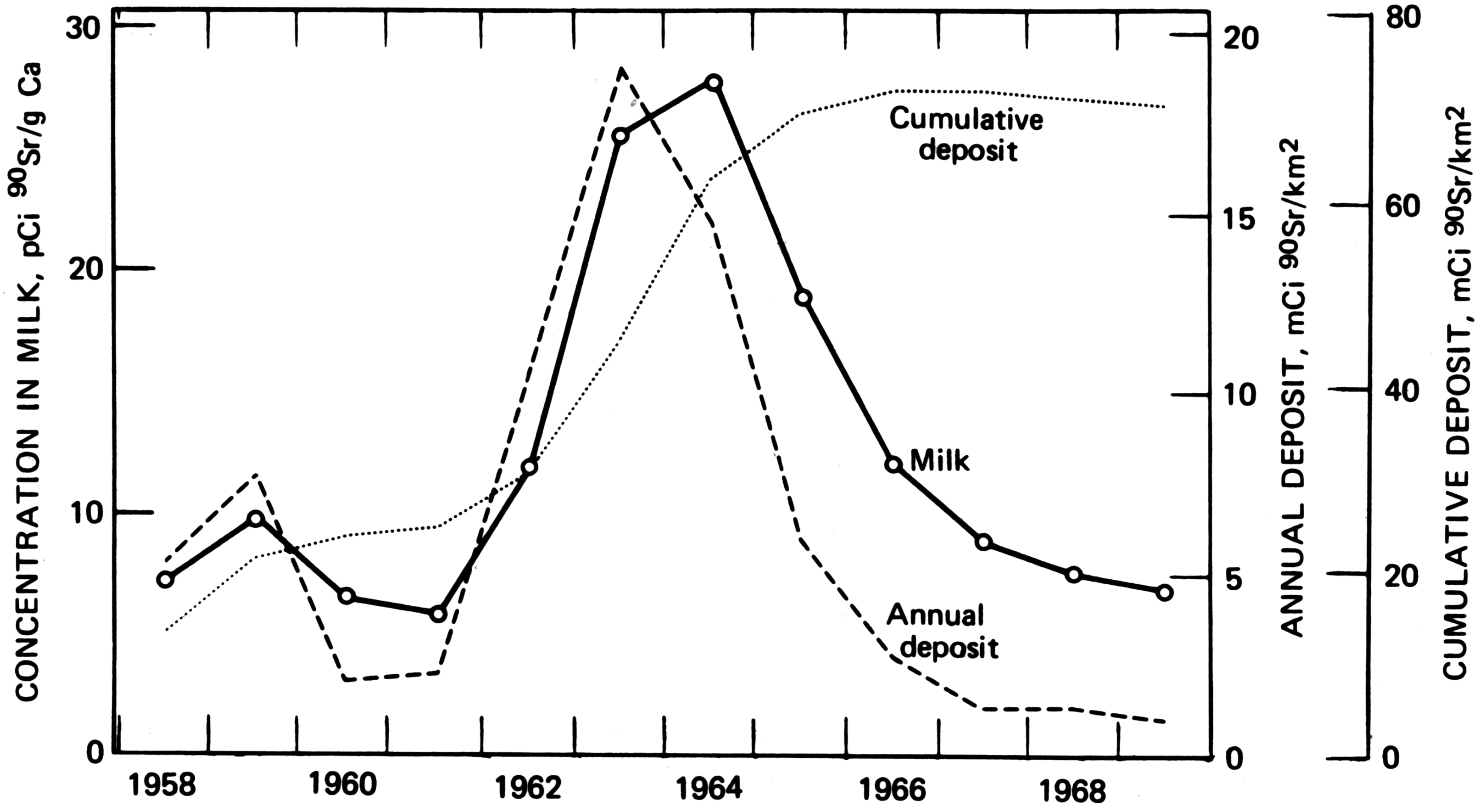

Fig. 1 Strontium-90 in fallout and milk in the United Kingdom, 1958 to 1969. Mean results of surveys of deposition and contamination in milk conducted by the Atomic Energy Research Establishment, Harwell,[31] and Letcombe Laboratory,[32] respectively.

THE EFFECTS OF EXTERNAL GAMMA RADIATION FROM RADIOACTIVE FALLOUT ON PLANTS, WITH SPECIAL REFERENCE TO CROP PRODUCTION

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ABSTRACT

This paper describes the major problems involved in attempting to predict for economically useful plants the degree of radiation damage that would arise from exposure to high-level radioactive fallout. Since almost no data exist on the deleterious effects inflicted on crops by actual fallout radiation, it is necessary to extrapolate from the existing radiobotanical data concerned with the effects of gamma radiation on survival and yield of plants.

A number of factors can modify the effects of the radiation and hence influence the accuracy of predictions of postattack injury. The most important variables are (1) species differences in interphase chromosome volume (the larger this value, the more sensitive the plant), (2) exposure rate (high rates are more effective than lower rates), (3) stage of development of the plant (a complex and difficult variable to assess), (4) postirradiation time (generally the longer the time, the greater the degree of damage), and (5) numerous environmental factors such as moisture, temperature, light, competition, etc., which normally modify plant growth and yield. These factors, acting singly or in various combinations, can have a considerable effect on the radiation response and thereby make more difficult the prediction of postattack injury.

Survival and yield data obtained from irradiation of growing plants are presented for many species. The most useful values in comparing sensitivities are LD_{10}, LD_{50}, and LD_{90} (exposures required to reduce survival by 10, 50, and 90%), and YD_{10}, YD_{50}, and YD_{90} (exposures required to reduce yield by 10, 50, and 90%). A log-log regression of LD_{10} vs. YD_{50} for 36-hr fallout-decay-simulation (FDS) gamma exposures has a slope not significantly different from +1; this indicates that, in general, an exposure producing an LD_{10} will reduce yield by 50%. Other LD_{10} values may also be predicted from regressions of interphase chromosome volume on LD_{10}.

Predicted YD_{50} values following FDS exposures are given for 89 crop plants and for 82 woody plants for a 16-hr constant-rate exposure. Using these predictions and the available radiobiological data, we can draw some conclusions concerning the vulnerability of crop plants to fallout radiation. The cereals (wheat, barley, oats, and maize), which are probably our most important group of crop plants, would be the most sensitive, having YD_{50} values ranging from about 1 to 4 kR (rice is much more resistant). The legumes (peas and beans) include both sensitive and resistant species, having YD_{50} values ranging from less than 1 to 12 kR. Root crops (onions, garlic, beets, potatoes, and radishes) have a wider range in

Table 11

SUMMARY OF RADIOSENSITIVITY DATA FOR MISCELLANEOUS FRUITS AND VEGETABLES

Plant	Stage irradiated	Type of exposure or exposure rate*	End point	Reduction from unirradiated control		
				YD_{10} or LD_{10} ± S.D., R	YD_{50} or LD_{50} ± S.D., R	YD_{90} or LD_{90} ± S.D., R
Cabbage, 'Ferrys Round Dutch'	Seedling†	FDS	Survival	8,550 ± 530	11,230 ± 300	13,900 ± 490
Lettuce, 'Summer Bibb'	Seedling†	FDS	Survival	4,380 ± 80	4,790 ± 50	5,200 ± 80
	Seedling†	FDS	Yield (whole plant)	4,310 ± 220	4,510 ± 180	5,040 ± 190
	Seedling†	8-hr CR	Survival	4,590 ± 110	5,030 ± 70	5,460 ± 130
	Seedling†	8-hr CR	Yield (whole plant)	3,340 ± 120	4,070 ± 70	6,070 ± 200
Pineapple, 'Smooth Cayenne'	Crown section[95]	Not given	Survival	5,510 ± 990	8,970 ± 850	18,440 ± 780
Spinach, 'Old Dominion'	Seedling†	FDS	Survival	8,410 ± 490	11,800 ± 400	15,100 ± 660
Squash, 'Royal Acorn'	Seedling†	FDS	Survival	4,170 ± 460	6,650 ± 300	9,140 ± 480
	Seedling†	FDS	Yield (whole plant)	3,850 ± 190	6,400 ± 200	
Strawberry, 'Takane'	Stolon[96]	17 R/min	Yield (fruit weight)	1,330 ± 650	6,530 ± 1860	20,800 ± 7300
Tomato, 'Rutgers'	Seedling†	16-hr CR	Survival	11,200 ± 460	13,300 ± 280	15,300 ± 440
	Seedling†	16-hr CR	Yield (fruit weight)	10,100 ± 480	12,100 ± 290	17,600 ± 800

*Yield data for other types of exposures are available for cabbage, lettuce, and squash.[39,50]
†A. H. Sparrow and P. J. Bottino, Brookhaven National Laboratory, 1970.

Table 12

SUMMARY OF RADIOSENSITIVITY DATA FOR PASTURE AND FORAGE CROPS

Plant	Stage irradiated	Type of exposure or exposure rate	End point	Reduction from unirradiated control: YD_{10} or LD_{10} ± S.D., R	YD_{50} or LD_{50} ± S.D., R	YD_{90} or LD_{90} ± S.D., R
Meadow fescue	3-week seedling*	30 R/min	Yield (whole plant)	3,030 ± 650	3,710 ± 580	5,570 ± 580
	7-week seedling*	30 R/min	Yield (whole plant)	1,500 ± 1070	2,480 ± 930	5,150 ± 1070
	3- + 7-week seedling*	30 R/min	Yield (whole plant)	2,830 ± 390	3,570 ± 350	5,580 ± 430
Perennial ryegrass	3-week seedling*	30 R/min	Yield (whole plant)		1,590 ± 1200	3,740 ± 1870
	7-week seedling*	30 R/min	Yield (whole plant)		1,930 ± 920	5,080 ± 2200
	3- + 7-week seedling*	30 R/min	Yield (whole plant)	1,090 ± 760	1,920 ± 590	4,170 ± 890
White clover	3-week seedling*	30 R/min	Yield (whole plant)	6,830 ± 1400	11,400 ± 1360	24,000† ± 3980
	7-week seedling*	30 R/min	Yield (whole plant)	6,450 ± 370	23,400 ± 970	69,900† ± 3930
	3- + 7-week seedling*	30 R/min	Yield (whole plant)	6,750 ± 2090	14,000 ± 2580	33,800† ± 9750
White clover, 'White Dutch'	Seedling‡	16-hr CR	Survival	20,300 ± 740	24,200 ± 540	28,100 ± 970
Crested wheatgrass	Seedling[97]	300 R/min	Survival	1,490 ± 850	2000 ± 720	3400 ± 630

*Communicated by R. S. Russell, Agricultural Research Council, Letcombe Laboratory, England, 1970.
†Extrapolated well beyond data points.
‡A. H. Sparrow and P. J. Bottino, Brookhaven National Laboratory, unpublished data, 1970.

gamma radiation required to produce a specified effect will be reduced proportionately.

Herbaceous Species

Cereals (Table 8). Five of the most important cereal crops, which vary appreciably in sensitivity, were studied. For FDS or 8-hr CR exposures to young seedlings, YD_{50} values vary from about 1.4 kR for barley to 4.5 kR for maize, with intermediate values of about 2.0 kR for oats and about 2.1 kR for wheat. No FDS data are available for rice, but for several reasons, it can be expected to be appreciably more resistant than maize. As is generally true, the higher-exposure-rate (30 or 50 R/min) data mostly show greater damage for a given total exposure. For instance, YD_{50} values vary from about 500 to 600 R for barley to 2.2 kR for oats; wheat and maize are intermediate, and rice, by far the most resistant, has a YD_{50} of about 14 kR. At present no yield data exist for three other major cereal crops, namely, rye, sorghum, and pearl millet.

It is known that stage of development at time of exposure influences yield (see previous discussion). Barley and wheat at young-seedling stages are more sensitive than at later stages.[53,54] However, data on lima beans,[52] corn, and rice (Fig. 4) indicate that in these plants meiotic stages are considerably more sensitive than the seedling stage.

We should keep in mind that varietal differences are known to exist for several cereals.[84-86] Differences are generally rather small, but in wheat varietal differences greater than fourfold have been demonstrated.[84]

Legumes (Table 9). So far four different edible legumes (peas, broad beans, lima beans, and soybeans) have been irradiated, and all are highly sensitive or have highly sensitive stages. The YD_{50} for seed yield after FDS seedling irradiation varies from about 1.0 kR for peas to about 3.3 kR for lima beans and, after high-exposure-rate treatments, about 200 R for broad beans. Flower-bud stages are much more sensitive, as shown by both the pea and the lima-bean experiments in which YD_{50} values of approximately 250 and 110 R, respectively, were found following high-dose-rate exposures.

Root Crops (Table 10). The five root crops so far studied vary from an FDS YD_{50} of about 1.4 kR for onions to 8.9 kR for radishes. However, poor texture and bad taste were noted in radishes grown from seedlings irradiated at the higher exposures. Potatoes and sugar beets irradiated at 80 R/min as young plants have YD_{50} values of 1.66 kR and 1.85 kR, respectively. More data are needed for sugar beets since the standard error is large. We should note, however, that reduction in sugar content may be more susceptible to radiation than reduction in root weight, and, as shown in one study, sugar content decreases at a faster rate (R. S. Russell, personal communication), but the decrease does not occur under chronic irradiation.[87] Only survival data are available for garlic; however, the LD_{50} of 1.12 kR indicates that this species is fairly sensitive with regard to yield reduction.

Miscellaneous Fruit and Vegetable Crops (Table 11). Experiments have been conducted with cabbage, lettuce, pineapples, spinach, squash, and tomatoes, but only survival data are available for cabbage, pineapples, and spinach, which have LD_{50} values of approximately 11.2 (FDS), 9.0, and 11.8 (FDS) kR, respectively. The tomato experiment is more difficult to summarize because the YD_{50} was highly dependent on time after irradiation. However, at 10 weeks after exposure, the YD_{50} was approximately 3 kR. Preliminary X-ray experiments with strawberries and raspberries irradiated in the dormant stage indicated only a mild effect on growth at a 16 kR exposure. No yield data were obtained (Sparrow, unpublished). Irradiation of strawberry stolons at 17 R/min produced a YD_{50} of about 6.5 kR. The survival data available for pineapple indicate that crown sections are rather resistant to irradiation, having an LD_{50} of about 9 kR. Limited data for irradiated sugarcane cuttings indicate an LD_{50} of approximately 3 kR.[88]

Pasture and Forage Crops (Table 12). Three grasses and two types of clover have been studied to date. Perennial rye has a YD_{50} of about 1.6 kR and is about one-half as resistant as meadow fescue, which has a YD_{50} of 3.7 kR. White clover, with a YD_{50} of 24 kR, is much more resistant than the grass species at any stage examined. For sweet clover, however, a severe effect (80% reduction) on growth was observed at 4.0 kR after 16-hr acute exposures (Sparrow, unpublished). Only survival data are available for crested wheatgrass and this only at an exposure rate 10 times as high as for white clover and the two grasses.

Woody Species (Fruit, Nut, and Forest Trees, etc.)

Many of the more important forest trees, especially gymnosperms, are extremely sensitive to X or gamma radiation.[9,11,12,26] Recently reported Soviet work has confirmed this high sensitivity by exposing trees to beta irradiation from a number of radionuclides using exposures extending over several years.[89] Brookhaven work showed LD_{50} values for a 16-hr exposure for

Table 13

LD_{50} FOR FIVE SPECIES OF COMMON COMMERCIAL HARDWOODS[11]

Common name	Species	$LD_{50} \pm$ S.D., R
Eastern red oak	*Quercus borealis* var. *maxima*	3650 ± 150
Yellow birch	*Betula lutea*	4280 ± 520
Sugar maple	*Acer saccharum*	4720 ± 150
Red maple	*Acer rubrum*	5110 ± 230
White ash	*Fraxinus americana*	7740 ± 260
	Average	5100 ± 700

THE IMPORTANCE OF TRITIUM IN THE CIVIL-DEFENSE CONTEXT

pp. 71–80.

Table 3 shows that the internal tritium dose rate at 2 wks after burst is 10,000 times less than the external gamma fission product dose rate –

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ABSTRACT

The importance of tritium in the civil-defense context is assessed by comparing the dose rate and the 30-year dose integral for tritium from fusion with the external dose of gamma-emitting fission products.

The tritium dose is computed by assuming equilibration of fallout tritium with water in the biosphere and with the body water of man. The fission-product gamma dose for late-time dose-significant nuclides is tabulated in roentgens per hour per kiloton per square mile as a function of time.

Tritium is shown to be relatively unimportant in the civil-defense context when compared with the external gamma dose from an equal yield of fission products.

The survival of man in an environment contaminated with radioactive fallout after a nuclear attack is the basis on which the importance of tritium in the civil-defense context can be assessed. Although tritium is a weak beta emitter, the radiation hazard to man can be significant because of the high yield of residual tritium from fusion devices. Also, tritium is relatively mobile and, as tritiated water, becomes rapidly dispersed in the environment where it is available for ingestion by man. On the other hand, the hazard is reduced somewhat by the dilution of tritium with the large amount of water in the environment.

The importance of any single isotope can only be compared with respect to other radioisotopes produced in a nuclear explosion. As a first estimate, therefore, the radiation hazard to man from residual tritium is compared with that from fission-product radioactivity.

When certain reasonable assumptions are made, the dose rate as a function of time and the 30-year dose integral can be determined per unit area and unit

assumes 2 gms/kt tritium (p. 74) and a body-residence time for tritium of 5 to 70 days (Sedan test data for 5 miles/kt).

In vivo biological half-residence time is like 4.2 days (p. 73).

EFFECTS OF BETA-GAMMA RADIATION OF EARTHWORMS UNDER SIMULATED-FALLOUT CONDITIONS

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ABSTRACT

Experiments on ^{60}Co gamma and $^{90}Sr-^{90}Y$ beta radiosensitivity of *Lumbricus terrestris* and dosimetry models of soil systems were designed to study the effects of fallout radiation on natural earthworm populations. Epithelial tissues (skin and/or intestinal) were the primary sites for radiation damage. The $LD_{50/30}$ days for gamma was 67.8 krads; no significant increase in mortality occurred for beta irradiations up to 102.4 krads. In situ dosimetry models with ^{137}Cs show that beta radiation is important only for direct contact (because of soil shielding) and that gamma radiation typically would contribute from 68 to 100% of the external body dose of natural populations. Habitat shielding, high radioresistance of earthworms, and radioactive decay preceding particle incorporation into soil suggest minimal population mortality due to radiation from anticipated weapon yields.

The delivery of external radiation exposure dose to biological systems at specific locations in a fallout field is generally in the form of an acute or short-term damage phenomenon.[1] Because of the paucity of data on effects of beta dose on invertebrates,[2] the effects of beta and gamma radiation from nuclear fallout generally had been assumed to be comparable. Recent information on contaminated-particle retention by vegetation[3] and contact doses from beta radiation[4] suggests that areas of serious damage to organisms from fallout will be larger than previously estimated from gamma radiation alone. Since fallout deposition initially tends to move toward and concentrate at the soil surface

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